Information Spaces in Urban Society

Analyses of Real and Virtual Worlds
&
Utilisation of Cyberspaces

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ABSTRACT

This study investigates the emerging information spaces from a geo-spatial perspective and explores the ways to utilise their flexible and dynamic nature. The recent growth of information communication technologies (ICTs) has resulted in the birth and development of a wide range of information communication spaces and cyberspaces. These spaces are increasingly affecting and contributing towards our society. Despite their remarkable growth, only few studies have been conducted on information spaces from the spatial perspective—treating these electronically generated spaces as a geographical entity is still rather uncommon in many disciplines. Nevertheless, users often acquire a certain degree of spatial awareness when they use the Internet, navigate on the Web, or explore one of the many 3D cyber cities. This study aims to uncover some of the spatial characteristics and the dynamics of information spaces so as to comprehend its spatial structure as well as the mechanism of its growth and, thereby, to contribute towards a better utilisation of such spaces.

The study first identifies the different types of information spaces and categorise them in terms of their spatial attributes. A subset of each space is then modelled, visualised and compared to its counterpart in the real world. In particular, we discuss the scaling tendency of the spatial distribution of each type of information space and compare them to those observed in the real world. A hypothetical model will be drawn from the comparison on the real and virtual worlds to help simulate the growth of information spaces. Based on these analytical insights, the latter half of the study comprises a series of case studies in which information spaces are utilised as a complementary facility to the real space. The case studies focus on the utilisation of virtual environments from the geographical and planning perspectives. The topics include (1) digitally enhancement of our aesthetic experience, (2) virtual reproduction of historic and remote places, and (3) construction of online, planning-support systems. The increased use of information technology is also discussed as a side-effect of ICT development; with a particular focus on the transition of the planning process as well as the formation of a ubiquitous computing society. The study concludes with discussions on the findings of these approaches and possible future directions stemming from this study.

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PREFACE

To attempt a comprehensive analysis of cyberspace at this time is perhaps a little premature, for the prevailing information communication technologies are still very much in the process of drastically altering the face of many spatial and geographical elements that have been regarded as beyond dispute until very recently. A full description of the history and the impacts of cyberspace, or an extensive narrative of the scenario for utilising such spaces, would in itself require a volume many times the size of this thesis, and readers must understand that they are asked to accept a work which can only be little more than an introduction to an ever so vast and continuously emerging subject.

This then, is an attempt to present an outline of the geographical portrait of our knowledge of cyberspace at its birth, which relates to, and may function as a mutually complementing space for, our real world. Its compatibility and utility in conjunction with the real world are also discussed through several applications. This includes a series of projects and analyses I have conducted on information spaces during my stay at the Centre for Advanced Spatial Analysis, University College, University of London.

This research was initially started as a storytelling on information spaces from the analytical perspective. However, as I proceeded with my research on the analysis of cyberspace, I became increasingly aware that my attempt would provide nothing more than an incomplete and fragmented picture of what was constantly changing and evolving. It was clear to me that incidental analyses of these spaces would not be sufficient for understanding the broader picture of the emergence and evolution of cyberspace, the amount of impact brought by these spaces on our lives, or whether they could indeed contribute towards the provision of a better service to our society.

It is precisely for this reason that this thesis consists of a series of studies that can be classified into two different but closely-related sections, one on analyses and the other on applications. What I present here comprises a collection of short case studies – first, the synthesis of my attempts to analyse such spaces, and second, a series of case studies through which I explored the ways we can utilise them. These two streams of studies share one common theme of trying to comprehend the very nature of information spaces from the geographic perspective in search of the greater social benefit.

The series of studies and analyses included in this thesis were carried out over a seven-year period, and some of the data used in earlier studies are inevitably outdated. Nevertheless, the insights deducted from these studies are believed to be fundamentally valid for the main purpose of describing the structure and the conceptual framework of information spaces for their better understanding.

I am indebted to many people for their advice, comments and suggestions. First and foremost, I wish to express my sincere gratitude to Professor J. Michael Batty of University College London for his many valuable suggestions and for supervising me.

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CHAPTER I

INTRODUCTION

Evolution of Information Space

1. INTRODUCTION

1.1 Internet, Cyberspace and Cyber Age

1.1.1 Dawn of the Information Age

The exponential growth of the Internet has had a significant impact on a number of social-economic activities in recent years (Cairncross 1995, 2001, Mitchell 1995, Braa *et al.* 2000, Kellerman 2002). Much of these changes — including the significant increase in the amount of online and wireless communications, restructuring of the organizations and businesses, and the growth of online trading and the digital economy — were made possible primarily through the rapid development of ICTs (Information Communication Technologies), or a range of technologies that support telecommunications and computer networking (Wilson and Corey 2000). In addition to increasing our opportunity and accessibility to engage in various activities, ICT development has also helped the computer networks to conceive a new "space" within which these activities take place. This virtual domain is commonly known as *cyberspace* or *information space* and comprises a variety of spaces that exist between the users and computers (Benedikt 1991, Batty 1997, Mitchell 2002). These spaces range from the physical infrastructure of computer networks to 3D cyber cities, governed by their distinctive spatial characteristics and social dynamics and are continuously expanding. In fact, they have grown at such a remarkable rate; as if they follow a unique time scale of their own that we often talk of *Internet years* or *Internet time* (Kitchin 1998a).

1.1.2 The Information Space as a Geographical Entity

Whilst their rapid and dynamic growth make it difficult to grasp the complete picture of information spaces, it is important to understand their overall structure—this is not only for the purpose of maintaining the efficiency of the various information services but also for predicting their future growth and thereby preventing, as best possible, any unfavourable scenarios for cyberspace development and uses to occur. Several analyses have been carried out on the structure and the growth of subsets of information space (Shum 1990, Abraham 1996, Bray 1996, Pirolli *et al.* 1996, Pitkow 1998, Huberman and Adamic 1999, Shiode and Dodge 1999a, 1999b, Wilson *et al.* 2001, O'Neill *et al.* 2003, Wang *et al.* 2003, Baker 2005); and the social implications of the growth of these spaces have also been studied (see for instance, Schroeder 1996, 2002). However, little has been discussed in terms of categorising and comparing amongst the different types of information space from the geo-spatial perspective (Batty 1997, Shiode 2000c), and practically no comparative studies have been conducted on the difference between the real and virtual spaces (Shiode and Batty 2000, Shiode and Torrens 2003a). In order to appreciate the diversity in the range of information spaces — and the online activities and opportunities that may emerge thereby — we need an extensive, comparative study on the range of information spaces.

Understanding the geographical distribution of information spaces, or their general spatial characteristics, also plays a vital role in planning their application (Horan 2000, Kotkin 2001). In general, as information spaces form an integral part of our social and economic development, their structure and characteristics are likely to reflect those of the real world (Gorman 1998, Mitchell 2000, Barabási 2003, Baker 2005). Analysis of information spaces could thus help us understand the growth and the distribution pattern of the information-based, social-economic and telecommunications activities, especially when compared with those of the real space. These insights would in turn help us identify where the concentration of information is taking place, evaluate their impact in the real world, and formulate the strategy for the investment of the relevant infrastructures (Wilson and Corey 2000, Graham and Marvin 2001).

In terms of utilising the information space, understanding their evolutionary steps as well as their spatial characteristics would let us identify powerful and useful applications that can be implemented in the virtual environment. In other words, it would provide us with an insight towards the exploration of information spaces as a medium to offer complementary functions to the present urban society. So far, many of the online applications have been developed empirically through trial-and-error with little research on the geo-spatial characteristics of the information spaces they were trying to utilise.

Another issue with the existing studies is that many of them apply statics rather than kinetics — geometry and topology, rather than morphology and spatial and dynamic distribution patterns — whenever referring to the structure and growth of these spaces.

Geographers and regional scientists have recently pointed out the problems of using geometry to explain the growth and morphology of socio-spatial entities such as the urban agglomeration (Krugman 1996, Fujita *et al.* 1999, Batty 2000). This is even more so when interpreting a rapidly evolving phenomenon such as the ICTs.

In sum, many of the existing studies fail to address the following questions from a spatial and a comprehensive perspective:

What is an information space? What kind of spatial variations does it comprise? How does an information space relate to the real space? Is there a way to model its structure and its growth in a generic form? What applications and utilities does it offer—that is, other than serving as a virtual sanctuary to a small group of computer literates? Could we utilise its spatial characteristics to support the formation of information-based, ubiquitous network society?

This study aims to address some of these questions by pursuing the following two approaches:

(1) On the one hand, it classifies the existing information spaces in terms of their spatial attributes as well as the degree of spatial awareness they offer. It examines a subset of each type of space through individual case studies and then proposes the conceptual framework of a spatial- temporal model for comparing the growth and structure of each space.

(2) On the other hand, this study pursues the possibility of utilising cyberspace, the flexible and dynamic nature of its space in particular, to support our social-economic activities. A series of case studies are carried out in this regard, each of which revealing the benefits and the shortfalls of cyberspace applications from different angles.

The structure of this thesis also reflects the combination of these two approaches; namely, the first half focuses on the analytical aspect; i.e. geo-spatial interpretation of subsets of various information spaces (Chapters 2, 3), while the second half showcases a series of applications; i.e. utilisation of information space for urban and social applications through a series of case studies (Chapters 4, 5).

The structure of this thesis will be discussed further in detail in Section 1.4.3. The rest of this chapter will discuss

(1) a brief summary on the history of information space, or the way such spaces have been conceived and evolved (Section 1.2),
(2) a review of related literature; i.e. what has been studied and discovered on these spaces (Section 1.3), and
(3) statement of the research objective, methodologies, the structure, and contribution of this study (Section 1.4).

1.2 A Brief History of Cyberspace

1.2.1 Emergence of Cyberspace: The Internet and Dawn of The Digital Era

Definition of Cyberspace

The term *cyberspace* is said to have been first introduced by Gibson (1984) in his science fiction novel, *Neuromancer*, where he used it for depicting a desperate, dystopian vision of the near future. The term somehow took off on its own, and its definition has been broadened, modified, and applied in many different contexts since then. Despite its popularity, or perhaps because of it, the definition of the term *cyberspace* is still undetermined after two decades, and we tend to use it as a general reference to all kinds of different spaces and concepts associated with the Internet and ICTs, including 3D cyber cities as well as data banks and networks (Benedikt 1991). This ambiguity is partly due to the way the Internet is regulated, where no single organisation administrates it as a system, but also because of the continuous growth of the computer networks and the constant changes in its services that make any rigid definition almost immediately obsolete (Mitchell 2002).

There are also several other terms that are used in the same or a similar context as *cyberspace*. These include *electronic space*, *information space*, and *virtual environment*. They, too, seem to lack a solid definition and are occasionally used in different ways (Graham and Marvin 1996).

In order to avoid confusion, this study will refer to each of these terms in the following context

(a) cyberspace: an online, pseudo-3D world of information networks with the ability to offer a sense of 3D space and place to its users and can be shared by multiple users through the information network.

(b) electronic space, digital space: a conceptual world of information network. Can be stand-alone or shared online, and could be used as a reference to a database, information network, or a single hard disk.

(c) virtual environment: a realistic representation of 3D space with or without additional sensory interface such as virtual gloves. May be a stand-alone environment.

(d) information space: any space associated with the computer network or the conceptual world of information as well as the electronic networks accessible via the Internet. The most comprehensive of all these terms.

From hereon, we will collectively refer to the various Internet-based and ICT-related spaces as *information spaces*.

Information space is occasionally compared to an unexplored frontier whose boundaries seem limitless (Whittle 1997, Cairncross 2001). In reality, information space is not an infinite or unbound territory, but a well defined, closed set of electronic domain that comprises a finite number of elements, if perhaps with the ability to expand near-infinitely (Shiode and Dodge 1999a).

The other definition that needs to be explicit regarding this study topic is the distinction between the real and virtual world. An attempt to define *virtual space* and *real space* could lead to a significant amount of debates, as it involves not only the physical contrast between the two worlds but also sociological, epistemological, and philosophical distinctions that arises from the ontology they represent to each of us. However, my position in this study is clear and simple in that we treat them purely from the geographical and spatial perspective, such that the real world would refer to places and spaces that physically exist as an entity on which we can walk about; whereas the virtual world is an electronically defined, hence electronically confined, space that does not have a physical entity on the earth surface (or elsewhere in the universe), regardless of how much spatial-awareness it may provide us with.

In other words, any social definitions of spatiality, territory, or socially defined institutions, such as workspace or public space are assumed contextual and will not used in this study. Instead, this study adopts geo-morphological definitions of spaces so as to focus on the geographical interpretation of information spaces.

1. INTRODUCTION

The Dawn of Digital Era: The Pre-Internet Communication

If we look back in time, there always were the predecessors of the current information spaces and electronic spaces. In fact, computers have assisted various aspects of our lives for nearly fifty years now (Mitchell 1995), and our interaction with the computers have constantly provided us with a certain degree of spatial awareness; for instance, in the form of a hard-disk space of a stand-alone machine as well as the network links amongst LANs (Local Area Networks) that were increasingly available at that time (Batty 1993).

Some stand-alone VR systems were also designed, as early as in 1980s, to provide a realistic virtual experience, typically through their proprietary interface such as a head-mounted display unit and a pair of sensory gloves. Software such as CAD (Computer Aided Design) or GIS (Geographic Information Systems) was also capable of providing a sense of space and orientation, for it handled spatial data and geographical contents occasionally supported by 3D visualisation effects (Curry 2003).

In addition, most computer games possessed an element of spatial awareness that allowed their players to *immersively inhabit* in its own invented world. Batty (1997) argues that they have been "often manifestly spatial and descriptive through their attempt to constitute a fictional reality or even portray the entity." Amongst these game environments is a branch of simulation games such as *SimCity* and *Civilization* that are intrinsically spatial and geographical in that they combine the real and the imaginary worlds that comply with the physics of the entity to a certain extent. Some of the basic adventure games, on the other hand, evolved to an interactive, multi-user space known as MUDS (Multi User Dungeon and DragonS or ~ DomainS) (Batty 1997, Hudson-Smith 2002, Maxis 2003).

These environments, regardless of whether they were the by-products of the interaction between a computer and its user, or created within a gaming environment, can be considered as predecessors to the information spaces we have today. However, there is one significant difference that distinguishes them from what we have today. In essence, they were conceived within a small, confined network, thus preventing their users to navigate through the broad space of the world-wide computer network. It also meant that access was only granted to a small number of registered users through the pre-registered computers, thus restricting public access.

1. INTRODUCTION

Internet as a Cyberspace Container

While some of the earlier, stand-alone virtual environments gave us a high level of spatial description, we seldom refer to them as cyberspace. The majority of these environments essentially lacked one factor — the immense spatial extent of information space that can be reached via world-wide computer network (Shields 2003). The essence of information space, then, is not determined by the level of details pursued by the visualisation efforts, or the number of computers locally available to each user, but the ability to reach out to a larger world via the electronic corridors of a virtual world connected at the world-wide scale in which we can *live* another life (Schroeder 2002).

Although such environment has been known to and was shared amongst the academics and research institutes since the 1970s, it was only after the Internet had been made public that such electronic space became available to the public at large (Kitchin 1998a). It was a turning point after which the users could explore and navigate through the wealth of information as well as disseminate information to a wider audience. It introduced a multi-user, multimedia environment in which users could communicate, collaborate and interact with other users and the surrounding virtual environment by using a standard desktop computer and a phone-line connection.

Ironically, the primary purpose of the Internet at its conception to secure a fail-safe, reliable online circuit has not been achieved, at least, not too its full extent. A system as complex as the Internet, especially in its present form, would never be free of errors and data losses caused by the defects of its own chaotic structure for that matter (Hafner and Lyon 1996). In fact, as it gained more popularity, the amount of electronic traffic on the Internet catapulted to an extraordinary level, and its loose security made it a vulnerable target for cyber attacks. All the same, it was this rapid growth of the Internet that brought forth the evolution of information spaces and its present prosperity.

As such, the emergence of information space was, despite described and anticipated in various science-fiction novels as otherwise, not deliberate but rather a natural consequence of the growth of the world-wide computer network (Hafner and Lyon 1996). The information space was bound to be dynamic and organic with geography of its own rather than being an integral part of the real world (Cairncross 2001, Wang *et al.* 2003, Baker 2005).

1.2.2 Evolution of Cyberspace: The Breakthrough

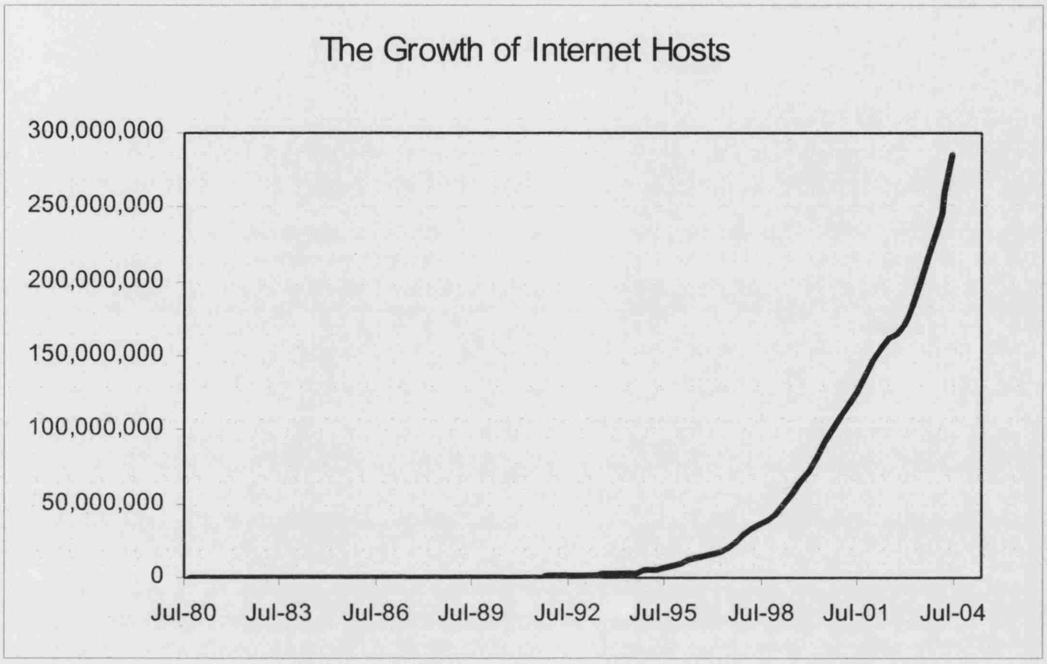
The Internet at Its Conception

We will not discuss the timeline of the Internet in detail, as it is well documented in literature (see, for instance, Salus 1995, Hafner and Lyon 1996, and Kellerman 2002). Generally speaking, since the first computer network was set up in 1969 with four nodes in the United States, small-scale LANs were gradually formulated in different parts of the world. By the middle of 1980s, a few local-scale, e-mail and telecommunication networks emerged — mostly within the academic domain with some industrial equivalent such as Ethernet developed by Xerox Parc — and these local networks gradually merged with one another. It was also during this period that commercial firms such as Compuserve and American OnLine launched their proprietary information communication services, offering the public the opportunity to link up. These private, regional networks, too, came to join the league of the then developing computer networks; and, ultimately, laid the foundation for the Internet as we know today. In terms of the spatial awareness, however, their text-based interface provided little more than that of telephone conversation, certainly no match to those offered by a proprietary virtual environment.

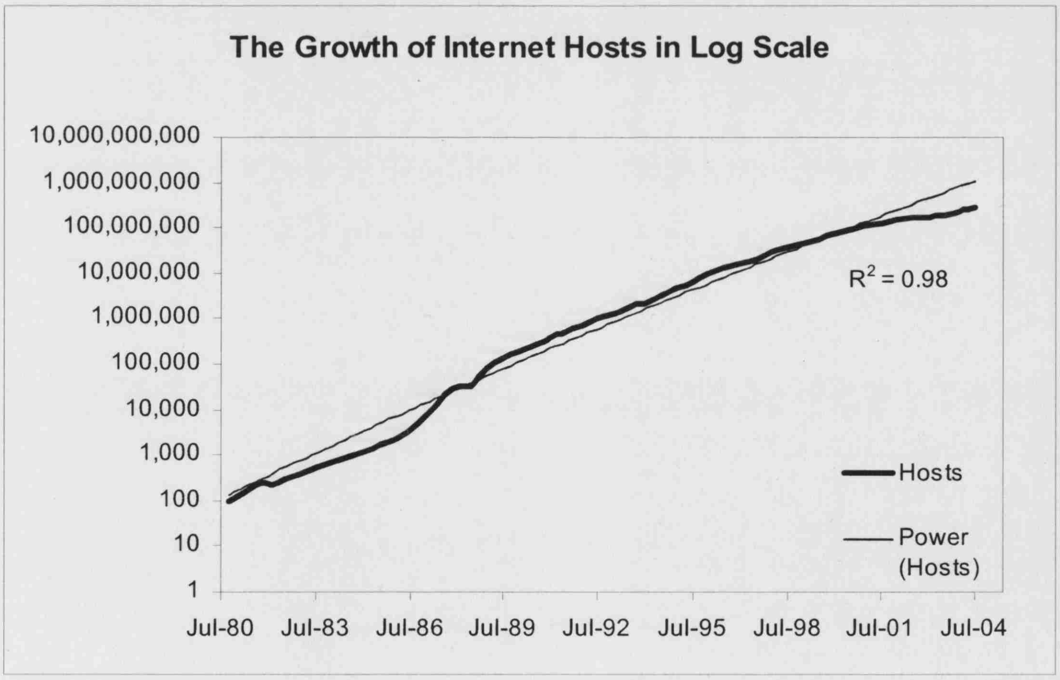
The Breakthrough

In 1990, the Internet achieved a remarkable growth after its dissemination to the public and commercial use. Introduction of the multimedia-enabled service immediately followed, first in the form of Mosaic, and later through the World-Wide Web. They boosted the exchange of multimedia contents furthermore, thus urging the emergence of visually enhanced cyberspace. The number of Web sites and their users roughly doubled every year, and online economic activities began to take a significant share in our economy.

Figure 1.2.1(a) shows the number of host machines registered on the Internet (Internet Software Consortium: ISC 2005). As of July 2004, the estimated number of Internet hosts is well over 285,000,000 (ISC 2005). **Figure 1.2.1(b)** shows a log-normal regression of the trend line which fits $y = c^{t-61.69}$ with r^2 =98.02%, where y and t respectively show the number of Internet hosts and time, and $c=2^{-274}$ for an annual interval.



(a)



(b)

Figure 1.2.1 Growth of the Internet on (a) a normal scale, and (b) the log-log scale (Data source: ISC (2005) Internet Domain Host Survey by Internet Society Consortium as of July 2004).

The slight decline in the recent growth rate of Internet hosts implies that the Internet may have completed its first phase of development and that it is now growing towards the formation of a more mature social-economic system. The discussion of the Internet and the web evolving into a more stable, mature system will be revisited later (Section 2.3).

Cyberspace as a 3D Environment

Reproduction of a virtual 3D space enabled the final leap to the immersive virtual environments. Since its introduction in 1994, Virtual Reality Modelling Language (VRML) (Pesce 1995) has become the *de facto* standard for creating 3D scenes within the Internet. Later versions such as VRML97 supported multi-user environments in which users could visually and verbally express their virtual presence and interact with other users in the same cyberspace. Similar products were offered by other groups (e.g. Viscape by Superscape, and the Blaxxun products by Blaxxun Technologies) shortly after that, and most of them featured multi-user capability and some of them also enabled the users to interact with the environment; i.e. change attributes such as the colour, size or shape of an object in the described virtual environment. The VRML initiative has recently evolved to the X3D format proposed by the Web3D Consortium (*www.web3d.org*), which provides a more powerful XML-encoded scene graphs.

The fact that we could build our own 3D environments and interact with other users online through our virtual representation known as avatars (Schroeder 2002) helped the increase in the number of cyber cities (e.g. AlphaWorld by *www.activeworlds.com*) and 3D chat environments (e.g. Cyber Place Community by Sony Lab.) (Okabe *et al.* 1998).

As a result of the emergence of various Internet services, a wide variety of modes and spaces now exist online, all of which have their own unique role and function. The layers of different information spaces complement each other and comprise the Internet space as a whole.

1.2.3 Beyond Cyberspace: Information Spaces and Ubiquitous Network

The relationship between the computer environment and its users also changed as more and more computers were introduced. Weiser (1993) proposed that the human-computer interaction can be divided into "three waves" of periods. He identified the breakdown of these waves as follows

First wave (1960~1980) — Mainframe: one computer, many people
Second wave (1980~2000) — Personal Computers: one person, one computer
Third wave (2000~) — Ubiquitous Computing: one person, many computers

In his analogy of the waves of computer resource, the first trend arrived with the development of a small number of mainframes, which were shared amongst many people. The access to, and the interaction with, a computing machine was a privilege then, which was typically granted after requesting the processing of a specific task. Naturally, punch cards and text-based command interface left little room for information space or electronic space to emerge.

The second wave of personal computing brought computers much closer to the users—initially, in the form of desktop PCs, and later, laptops and wireless, handheld devices. The one-to-one correspondence between the user and the personal computing device enhanced our ability to interact with computers on a much more personal level. It helped us build an electronic space (1) within the computer—in the form of hard disk storage, and also (2) between the user and the computer—as an interactive function enabled through the keyboard input and the display output (Batty 1993).

The transition of the computer user interface from the text-based command lines to GUI (Graphic User Interface) also helped increase the degree of spatial awareness. In particular, they took on the metaphor of a virtual office and electronic work place, where users would open a task as a "window" (or x-window) utilising, if implicitly, the ability of personal computers to act as a doorway to the virtual, electronic spaces. Still, the spatial interaction between a computer and its user was, by large, a personal experience. Introduction of LANs and online chat/gaming environments helped enhance the extent of interactive space for each user, but the number of users connected to such network was still small, and the amount of information exchanged was also limited as the prevailing technology of the time was largely based on text and static images. This changed dramatically after the Internet has been made publicly available.

The third generation of computing waves was then expected to bring forth the state of abundant technology. Weiser (1991, 1993), along with his colleagues at Xerox Laboratory in Palo Alto, suggested that *ubiquitous computing* or the *calm technology* would form the third wave in computing, which was just starting to take shape in the 1990s. According to their model, computers would become available in every room and place—with microchips embedded in most household items—so that technology would recede into the background of our lives.

The number of computers available to each user has indeed been continuously growing since, and the general idea of abundant computing resource has been realised in principle. However, these computers, regardless of whether they are a desktop machine or a small handheld device, remain largely visible and are an increasingly essential component of our lives. Also, the role of computers has significantly changed following the rise of the Internet. We became increasingly reliant on the network of computers—rather than on the computer itself on such network—and these networks began to support us share and exchange data with other users worldwide.

As the Internet developed, software, information and communication, as well as the network structure that enables such communication, became more and more important; so much so that the benchmark for the state of ubiquity and abundant technology are now being measured by accessibility (how fast we can access and retrieve online information) and opportunity (what we can do with that information), rather than the number of hardware and computing resource around us (Shiode 2004).

In this light, the last of the three waves of human-computer interaction predicted by Weiser (1993) can be further divided into two separate phases where it initially achieves (1) the abundance in the number of computers per capita, which subsequently would result in (2) the increase in the amount of interaction between computers, and many users and computers communicate online in a synchronous fashion. This latter phase could be identified as a separate phenomenon, forming a "wave" of its own:

Fourth wave — Ubiquitous Network Computing: many people sharing many computers and information online

In the ubiquitously connected society, people would have the ability to continuously access and communicate online via their handheld devices as well as through the seamless network that are embedded in the urban environment (Hunter 2002, Shiode 2004). We will revisit at a later chapter (Section 6.2), the rise of a ubiquitous, pervasive computing environment and its potential impact on the formation of an information network-based society.

1.3 Related Studies on Information Spaces

Although the Internet saw a significant growth only in the last decade, it has already attracted a number of researchers to conduct various kinds of surveys and investigations on its size and distribution. A vast amount of statistical resource as well as several theoretical contributions to interpreting the growth of the Internet and information spaces exists, and these research efforts are becoming increasingly evident in a number of different disciplinary areas. Among the many studies conducted on the Internet and information spaces so far, four major streams of approaches can be identified.

1.3.1 Statistical Approaches Based on Data Summaries

The most obvious yet vital method for grasping the overall impression of the Internet is to collect information from a randomly selected sample set and apply inferential statistics (Best and Krueger 2004). A number of researchers and organisations have attempted to capture the state of the Internet by surveying the number of Web sites, active servers, users of the Internet as well as their growth rate (including Gray 1995, Bray 1996, Coffman and Odlyzko 1998, OCLC 1999, Net Factual 2003, ISC 2005).

In terms of the number of web servers, for instance, Net Craft (2005) suggests that their pinging survey collected responses from 58,194,836 sites as of January 2005, maintaining a similar growth rate as the Internet hosts since the mid-1990s. Several other organizations and companies list their own estimates on the growth of the Internet and the Web. However, they vary in the accuracy of their survey and occasionally suffer from lack of updates, making their data obsolete in the fast growing field of the Internet statistics. Some examples include Online Computer Library Center (1999) and Network Wizards (1999), whose survey revealed that the total number of Web sites was estimated at around 4,882,000 worldwide, with an average value of 129 pages[1] per site (as of June 1999) but have not been updated since. Similarly, Net Names (2000)

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[1] This study distinguishes the range of different units of web spaces as follows (1) a web domain: a unique domain name hosted by a server (e.g. *http://www.ucl.ac.uk/*), (2) a web site: a domain or a sub-domain that comprises of a collection of information and can be contained under a folder (*http://www.ucl.ac.uk/dpu/*) (3) a web page: a single document or a composition of frames, short or long, typically in the form of HTML, XML and alike, that can be viewed by scrolling down the side bar (e.g. *http://www.casa.ucl.ac.uk/naru/index.html*).

published that the total number of domains names to be in excess of 15,000,000 (as of January 2000), followed by the 31,041,287 domains estimated by Net Factual (2003) as of October 2003.

With some exceptions, these statistics tend to be collected by computer scientists and analysts working in a research institute of academic or commercial nature. These methods are useful for providing an estimate of the overall size of the information space as well as forecasting the trend of its growth through observations conducted over time. However, due to the exponential growth rate of the Internet and its increasingly complex structure, most of these figures inevitably consist of coarse estimates, or a rough indicator of its scale (Network Wizards 1999), making it less accurate and less reliable than it would be in the case of measuring a more mature social-economic distribution (Shiode and Batty 2000). Also, the fact that they comprise statistical, aggregate data restricts any detailed interpretation of the spatial or social attributes of the information space. We should note, however, that, in terms of the increase in the number of users of the Internet, Hannemyr (2003) demonstrates that the growth rate is comparable to those of the adoption rate of other technologies such as the telephone, the radio, or the television, when they were first introduced.

1.3.2 Data Mining that Uncovers Anomalies and Clusters

In contrast to the statistical approach, a data-mining approach typically focuses on a single local spot or on a particular point of interest. The underlying idea is to carry out an in-depth analysis of the targeted area so as to appreciate the exact impact and local effects of the observed phenomena in more detail (Mena 1999). Data mining of information spaces became particularly popular in the late 1990s, when the emerging information spaces needed detailed analysis at a local scale. Examples include the measurement of local traffic distance in the information space (Murnion and Healey 1998) and distribution of IP address blocks of a country at the postcode level (Shiode and Dodge 1999a). Several international conference series have also stemmed from such trend and are now forming one of the mainstream research areas in the field of information analysis (see, for instance, Proceedings for IEEE International Conference on Data Mining 2001~2003). The purpose of these studies may vary and the types of people who carry out these studies also seem to follow no particular patterns. Data mining proves to be especially useful when exploring the spatial pattern of a finite and relatively small study area. It also provides the possibility to conduct further analysis on the collected data for a detailed examination and model construction. The only limitation is that, such method is only applicable for interpreting a subset of information space. It is practically impossible to maintain the same level of detail if the entire information space was to be studied, although we invariably so wish.

1.3.3 Visualisation of the Graphical Representation of Data

Most of the services provided by the Internet such as the World Wide Web consist of electronic contents and have practically no physical entity. This makes it difficult to geographically "locate" and visualise their position. Nonetheless, various cartographic and geo-information techniques have been applied to visualise this virtual domain from a variety of perspective (see for instance, Dodge and Kitchin 2000, and Kitchin and Dodge 2002 for an archival catalogue of such efforts. CAIDA 2002 and Dodge 2005 (www.cybergeography.org) also provides an online archive of the major visualization projects and their results). Some studies address the pattern displayed by search queries (Carriere and Kazman 1999) and the abstract information worlds (Fabrikant 2003, Fabrikant and Skupin 2005), while others depict the topological connectivity of the hyperlinks (Shiode and Dodge 1999b). Many of such attempts have been made by cartographers and social scientists in the field of GIS (Wang *et al.* 2003).

Cartographic visualisation, if properly applied, may provide a persuasive and intuitively comprehensible output. Fabrikant (2003) points out that the visualisation of information space based on the cartographic design guidelines would enable its designers to construct a conceptually robust and usable information plain and also helps users extract knowledge from massive digital data archives more efficiently. They can indeed offer interesting and useful insights for the comprehension of the distribution of information spaces, thus acting as a navigation map for that particular type of space.

However, cartographic interpretation of information spaces tends to be self-conclusive in that the extent of the visualised space is limited by the selection of the original dataset. Also, there is a trade-off between the degree of complexity and elaboration of the visualisation technique, and that of its applicability to and compatibility with a wider range of information. For instance, KartOO Technologies (*www.kartoo.com*) shows the result of a search query with its proprietary graphic interface and displays the connectivity among the relevant sites using its unique cartographic technique. However, the result is dependent on the data recorded in its meta-search database, and its interface is not suitable for illustrating the wider spatial distribution of the information space.

1.3.4 Model-Based Approaches Employing Theoretical Tools

The final approach aims to understand the Internet by constructing a model of its structure. Most of the models used in such studies are an adoption of those developed in other fields. For instance, there is a stream of studies on the expansion of spatial interaction models which aims to provide the accessibility or the latency measure within the changing geography of information space (Janelle and Hodge 2000). These include the attempt to interpret the urban landscape in terms of the degrees of association or spatial clustering associated with certain aspects of information flows (Marvin and Graham 1992, Ord and Getis 1995), as well as a more straightforward measurement of accessibility and the geography of opportunity (Shen 1998, Baker 2005). They have been used in the past for estimating the accessibility and opportunity within the real geographic space but, with some minor adjustment, can be also applied to the interpretation of multiple layers of cyberspaces.

Similarly, there is an extensive collection of studies on its connectivity and topological structure (Abraham 1996, Kleinberg 1997, Wheeler and O'Kelly 1999, Barabási 2003). Many of them draw on the concepts conceived in social science such as co-citation analysis and social network theory. In fact, one such study takes on the idea of social networks that reflects the 'small world' assumption (Watts and Strogatz 1998). The underlying idea is that, for a variety of global network phenomena, all objects or people are connected to one another within a chain of six acquaintances, which is popularly known as the 'six degrees of separation.' Albert *et al.* (1999) have applied this concept to measure the degree of connectivity of the Web, predicting that Web pages are separated by an average of '19 clicks.' This connectivity measurement is closely linked to the idea of power laws describing networks where "... the probability of finding documents with a large number of links is significant, as the network connectivity is dominated by highly connected Web pages." (Albert *et al.* 1999).

Also, a research group at IBM Lab tried to measure the popularity of web pages by the number of hyperlinks within other pages that point to that page. The origin and destination of these hyperlinks were then modelled and compared to the shape of a bow-tie (IBM Almaden 2000).

Research Approach Adopted in This Study

This study adopts and combines each of the above-mentioned methods to understand the geography of information space. It first uses the statistical and data-mining techniques to collect data on a subset of each type of information space and also employs several visualisation techniques to express the distribution of such spaces (Sections 2.2~2.4). It then conducts a rank-size analysis of the information spaces including the global domains and IP address blocks, based on the number of countries and Web page hyperlinks within and between them (Chapter 3). The theoretical standpoint as well as the underlying assumptions on which this study is based are discussed further in Section 1.4 to provide the readers with a better picture of where this study is situated within the broader body of research literature, and what the limitations of this study is.

The case studies that are showcased through Sections 2.2~2.4 also observe the morphology of the information spaces discussed; i.e. the spatial pattern of information and cyberspaces. This aspect is further discussed in Chapter 3, where the relative frequency of the size distribution of elements within them is studied in terms of their rank-size distribution. Some of these distributions will be compared with the conventional social and economic distributions of the real world such as national population and real GDP, to interpret the growth and the maturity of information space as a social-economic system. The next section explains the methodologies in more detail and also argues the originality and contribution of this thesis. It also discusses the position of this study relative to the larger literature and where it stands among the other research contributions from the academic community in general.

1.4 Methodology and the Structure of Thesis

1.4.1 Research Objectives

As we saw in Section 1.2, the brief summary of the development of the Internet makes it clear that information spaces are a relatively new but fast growing and evolving entities. However, much of the existing literature seems to concentrate on the study of Internet statistics and its interpretation as a social index. They also tend to perceive it as another means of communication, rather than that of a newly conceived spatial dimension. Information spaces can indeed offer a new way of communication, for instance, in the form of an IP-phone, but its potential applications exceed the framework of our conventional social-economic activities (Wilson and Corey 2000). It offers a new space in which the increasingly rapid shift of economy can be better accommodated, a space where activities that are difficult to realise in the real world can be simulated, and a space that keeps growing and evolving as more resource, users, and contents are added. Yet the nature of information spaces is still widely unknown to us. In fact, it is the continuous growth of its spatial extent that makes the study of information space—especially that from a geographical and structural viewpoint—a new and relatively unknown avenue of research.

This study stems from the following research question: *Can we measure, appreciate and understand the emerging new information "spaces" in geographical and physical terms?* In other words, the theme central to this study concerns with the increase in our understanding of the geography of information spaces such as their growth, distribution and the spatial characteristics in general.

As such, the greater portion of this study takes a structural and quantitative view, rather than a sociological or qualitative, of information spaces. It assumes that information spaces possess spatial properties that are comparable to those of the real world we live in, and it treats information spaces as a measurable, finite, and mappable universe subject to geographical and geo-morphological interpretation. In other words, the approach adopted in this study is generally confined to that of spatial analysis and modelling, which originates from the quantitative revolution that took place in the 1960s and has been pursued by a number of regional scientists and quantitative geographers alike.

This is not withstanding the fact that a significant amount of efforts and contributions have been made by researchers in the related disciplines of sociology, social science, communications, and computer science (see for instance, Schroeder 1996, 1997, 2002, Kopomaa 2000, Webb 2001, Dahlberg 2001, Mitchell 2003, Shields 2003, McCollough 2004). Specifically, these include the sociology of science and technology, social interactions and environmental behaviour in virtual spaces, or within a CSCW (computer-supported collaborative work) environment. They address very interesting and important research questions such as how we perceive information spaces, how we behave in such environment, and how we interact with others in a digital manner.

However, the scope of this study is different in that it pursues the structural and geo-morphological understanding of these spaces, with which we could gain a better understanding of information spaces as a structure that can be quantitatively modelled, visually represented as well as its growth forecasted. In particular, this thesis aims to analyse some of the spatial characteristics of information spaces so as to comprehend its spatial structure and, thereby, to contribute towards a better utilisation of such spaces. The objective of this study, in particular, is two-fold: first, <u>it aims to interpret the wide range of information spaces from a geo-spatial perspective</u>, and, second, <u>it explores the ways to utilise the flexible and dynamic nature of such spaces</u>.

The former (Chapters 2, 3) provides an analytical insight towards the better understanding of the spatial characteristics and distributions of information spaces. The underlying assumption here is that, regardless of the lack of their physical representation, information spaces can be treated as a spatial and geographical entity within which users can engage in various social-economic activities, if with some limitations as well as distinctions from the real world. The thesis will first identify and categorise the information spaces in terms of their spatial attributes. A subset of each space is then visualised and compared to its counterpart in the real world. Deriving from this comparison of real and virtual worlds, a hypothetical model is constructed where the distribution pattern of elements within information spaces is simulated and compared to those in the real world. The objective here is to propose a method to understand and interpret the geographical features of information spaces.

Based on these analytical insights, the latter half of the study (Chapters 4, 5) explores the ways to utilise the dynamic and flexible nature of information spaces through a series of case studies. These include the exploration of the electronic interactivity for aesthetic approach, dynamic production of a customised space, virtual reproduction of historic landscapes with 3D VR models, and implementation of online decision support systems. The main objective shared by the range of case studies is to examine the usefulness of information spaces as a complementary facility to the real space, which is based on the assumption that information spaces are a comparable and closely linked system to their real world equivalents.

1.4.2 The Significance and Contribution of this Study

The fact that this thesis addresses the analysis and application of a recently evolved subject such as the Internet makes its findings timely and opportune. In particular, the information spaces as we know today, with its ability to communicate worldwide, have been developed only for over a decade, and an academic endeavour on its interpretation as a geographical domain is still a pioneering task in itself.

This is not withstanding the fact that, as discussed in Section 1.3, several notable approaches have been already taken by scholars from a wide range of disciplines. However, many of such research efforts focus on one particular example of information space, typically on a small subset of a particular type of space. Also, they tend to treat cyberspace as a subject of another social-economic index and that only, thus failing to discuss the geo-spatial aspects of these new spaces.

In contrast, this thesis makes one of the first attempts to look at the diverse range of information spaces as a collective entity of geographical domains. Interpreting these spaces from a geographic perspective and classifying them by their spatial characteristics are in itself a novel contribution towards the understanding of their spatial structure. The methods employed in the analysis are mostly adopted from other existing fields, but its application to the interpretation of a variety of information spaces, especially when combined with the comparison between the real and virtual spaces, is believed to be a unique achievement.

In addition, this study explores the prospect of utilising the flexible and dynamic nature observed in the spatial attributes of information spaces. It pursues the possibilities of utilising these spaces to achieve a new application, and it does so through a wide range of case studies each of which proposing novel approaches and applications. The empirical method applied here would, hopefully, help find ways to put these spaces to a better and effective use for our society in the future.

The study also discusses the impact of the development of ICTs and cyberspace evolution, and how they might support—or indeed contribute towards—the planning, management, and development of our society. As these impacts are hard to foresee at this stage, much of the claims made in this study may turn out to be little more than speculative. However, recent developments of information spaces and the wireless technologies imply that the rise of pervasive computing and ubiquitous network communities may be a feasible and likely scenario for our society to follow (Shiode *et al.* 2003).

As this study is based on a series of separately conducted studies and analyses, it may prove to be exploratory in places, rather than comprehensive; both in terms of their depth and their topical areas. To some extent, this is inevitable when dealing with a massive and complex object as the information space. That said, this study focuses on one particular theme of understanding the very nature of the information space from the geographic perspective—which I sincerely hope will make a novel contribution.

1.4.3 The Methodology towards the Understanding of Internet Geography

The methodology applied in this study is, in the first instance, quantitative analysis of a subset of each type of information spaces so as to grasp the spatial characteristics of the information space as a whole. In particular, it perceives the range of information spaces from a structural viewpoint rather than based on their contents, as identified by Fagrell and Sørensen (1999). For instance, in Section 2.3 where a subset of the web space is discussed, this study "attempts to measure the site hierarchy, depth and width of the link tree" (Fagrell and Sørensen 1999). It also brings forth the comparison between information spaces and the real world equivalence; which in turn summarises the benefits and shortfalls of utilising information spaces.

Studying a subject that is as closely connected with the multiple facets of our lives and society as information space is—and doing so without actually considering its sociological and contextual aspects—is naturally impracticable for establishing a social theory. Consequently its result is confined to the understanding of the generic spatial pattern presented by information spaces as a whole and how these spaces can be distinguished using spatial typology.

What is being examined in this study is the quantitative and geo-morphological interpretation of information spaces with the assumption that the result of such study will be the same with or without considering their sociological and contextual aspect.

Based on the differences observed in their spatial attributes, the information spaces are categorised into four different groups, each of which is then studied closely through the analysis of its subsets. Their geographical distribution and the visual representations are further discussed, alongside a comparison with their counterpart in the real world. This analysis will lead the way to form the conceptual model of the scaling distribution of these virtual entities.

Based on this discussion, we carry out three case studies, each of which aiming at a particular way to utilise the flexible nature of cyberspace. The results obtained from these case studies will be reviewed and discussed in the concluding chapter to propose a scenario for the transition of spaces and their impacts upon various social and urban activities. The case studies will focus on the utilisation of virtual environments from the geographical and planning perspective, and they propose their application as

(1) online-planning-support systems,
(2) virtual and dynamic museum space, and
(3) virtual reproduction of historic and remote places.

The series of projects and analyses included in this study were conducted over a seven years of time. Some of the data used in earlier studies are inevitably outdated. As we are dealing with a fast growing and evolving phenomena such as information spaces, there is a distinctive possibility that the time of data collection could make a difference on the result. Nevertheless, the insights deducted from these studies are believed to be fundamentally valid for the main purpose of describing the structure and the conceptual framework of information spaces for the better understanding of geography of information spaces.

1.4.4 Structure of This Thesis

This thesis consists of four different components that are formed around the single theme of interpreting the information space:

(1) Introduction (Chapter 1): introduction, history, the context setting
(2) Analysis (Chapters 2 and 3): typology, spatial analysis and modelling
(3) Application (Chapters 4 and 5): spatial applications and planning
(4) Conclusion (Chapter 6): summary of findings and future research plans

Here is a brief synopsis of each component.

Introduction: The introduction, which is this very chapter, sets the context for the entire thesis. It provides a narrative for the increasingly pervasive ICTs, briefly depicts the history of information spaces, reviews the related studies, and clarifies the purpose, and the significance of this study.

Analysis: The second part comprises two tightly-connected components (Chapters 2 and 3) on the geography of information spaces and its analytical aspect. Chapter 2 starts by proposing a classification of information spaces into four basic categories (Section 2.1). It then proceeds to explore them by examining subsets of each space and comparing them to their counterpart in the real world (Sections 2.2~2.4) by using the methods explained in the previous section. In particular, Section 2.2 discusses the geography of the Internet, or spatial analysis of Internet "real estate," and compares the distribution of the Internet address to those in the real space. Section 2.3 proposes to define a notion of distance within the metaphorical space of the World Wide Web and visualises the spatial distribution of its subset by overlaying it on top of a real-world map. Here again we compare the statistics of the real and virtual worlds to emphasise the rise of cyberspace economy. Finally, Section 2.4 studies the spatial distribution of an existing cyber city and its growth in comparison to that of a real city.

These analytical studies are by no means comprehensive, but they help us understand the spatial characteristics represented by each space and thus provide the ground for the modelling effort made in Chapter 3. In Chapter 3, some of the findings from Chapter 2 will be incorporated and expanded in the form of a model with respect to the scaling tendency with respect to the distribution of size of elements within such space. It provides a brief introduction to the theory of scaling distribution, namely the rank-size rule, and applies it as a measure to indicate the degree of maturity of the information space as a social-economic system. This is followed by the formation of a conceptual growth model of the information space that simulates the scaling distribution of these spaces.

Application: Drawing from the analytical insights obtained in the above, the third part of this thesis describes a series of applications that would utilise the flexibility of information spaces and its interactivity with the real world.

Chapter 4 consists of three of my case studies that explore the way we can utilise the flexible nature of information spaces. These studies are conducted independent of each other but are formed around the common theme of art and cultural practice. The virtual art gallery project (chapter 4.1) pursues the prospect of supporting a unique art experience by dynamically creating a customised art gallery within cyberspace. The interactive art experience project (Section 4.2) explores the electronic interactivity for aesthetic approach by using multimedia interface in cyberspace to enrich our art experience. Finally, the Digital Egypt project (Section 4.3) examines the effectiveness of an online teaching and learning resource through the reproduction and distribution of a historic landscape in the forms of 3D VR environment and other online learning contents.

The attempt to utilise information space is pursued further in Chapter 5. Here, information space is identified as a medium that closely relates to, and reciprocally depends on each other with, our society represented in the real space. Focused on the theme of planning, this chapter aims to utilise information space as a container for 3D city models and visualisation efforts (Section 5.1), a collaborative working environment in which to develop a multi-user decision support system (Section 5.2). It also studies the impact of ICT development towards the planning paradigm and its process (Section 5.3).

Conclusion: The final component (Chapter 6) provides an overall summary of the analyses and case studies conducted in this thesis. It examines the insights on information spaces gained through these studies and discusses the prospect of utilising information spaces from the geographical and social perspective. The chapter concludes by covering the contribution of this thesis as well as some notes on our expectations and anticipations towards the next generation of information spaces and their possible impacts from the social-economic perspectives to help identify future research directions.

From the geo-spatial perspective, the analytical components (Chapters 2 and 3) and the application components (Chapters 4 and 5) respectively focus on the following set of information spaces and their features:

Analysis and Modelling

(a)Internet space: spatial pattern (Section 2.2), frequency of size (Section 3.1)

(b)Web space: spatial pattern (Section 2.3) and frequency of size (Section 3.2)

(c)Virtual city space: morphology (Section 2.4), frequency of size (Section 3.3)

Applications

(a)Virtual museum space: 3D interactive environment (Section 4.1), and accessibility and online aesthetic experience (Section 4.2)

(b)Virtual archaeology space: 3D models of built environments (Section 4.3)

(c)Virtual city space: 3D city models (Section 5.1)

(d)Virtual planning space: 3D multi-user planning support systems (Section 5.2) and the impact of ICT towards planning (Section 5.3)

(e)Ubiquitous network space: divergence of information spaces (Section 6.2)

1.4.5 Published Papers Relevant to This Thesis

As aforementioned, this thesis is based on a series of studies conducted on information spaces during my stay at University College, University of London. The contents are thus closely related to many of my publications that were produced between April 1997 and July 2003. The following table shows the details of these publications with a reference to the most relevant section within this thesis.

1 Introduction

Shiode N (2000a) A brief history of cyberspace: evolution of information spaces. *INET'2000*, Yokohama, Japan, July 2000.

1. INTRODUCTION

2 Geography of Information Space

2.2 Internet

Shiode N (1999b) Geographic analysis of information space: interpretation and visualisation of Internet space in the geographic context. *Virtual Conference on GIS (VCGIS'99)*, GIS Association of Japan, April 1999.

Shiode N (2000b) Analysing the micro-geography of the Internet. *The 29th International Geographical Congress*, Seoul, South Korea, August 2000.

Shiode N and Dodge M (1999a) Visualising the spatial pattern of Internet address space in the United Kingdom. In B. Gittings (ed.), *Innovations in GIS 6*, London: Taylor and Francis, pp.105-118 [book chapter].

Dodge M and Shiode N (2000) Where on earth is the Internet? - An empirical investigation of the geography of Internet real estate. In J.O. Wheeler and Y. Aoyama (eds.), *Cities in the Telecommunications Age: The Fracturing of Geographies*, London: Routledge, pp.43-53 [book chapter].

2.3 Web

Shiode N (1999c) Network analysis on the global hyperlink structure of the information space. *International Federation of Operational Research Societies*, Beijing, China, August 1999.

Shiode N and Dodge M (1999b) Spatial analysis of the World Wide Web. *NETCOM* **13**: 9-24 [journal article].

Shiode N and Dodge M (2000) Spatial analysis on the connectivity of information space. *Theory and Applications of GIS* **8**(2): 17-24 [journal article].

Shiode N (2001b) Visualisation of the metaphorical info-structure: Interpreting the World Wide Web in the context of real geography. *GeoInformatics* **4**(3): 27-28.

2.4 Cyberspace, Hybrid and Real Space

Shiode N (1998) Modelling the structure of cyberspace as a fractal network. *Proceedings of International Conference on Modeling Geographical and Environmental Systems with Geographical Information Systems*, Hong Kong, China, June 1998, pp.640-644.

Shiode N and Torrens P (2003b) A preliminary analysis on the fractal structure of urban sprawl dynamics. *The 6th Sharjah Urban Planning Symposium*, Sharjah, UAE, June 2003 [received "The Best International Paper" award].

Shiode N, Li C, Batty M, Longley P and Maguire D (2003) The impact and penetration of location-based services. In H. A. Karimi and A. Hammad (eds.), *Telegeoinformatics: Location Based Computing and Services*, London: CRC Press, Chapter 12, pp. 349-366 [book chapter].

3 Modelling Cyberspace

Shiode N and Batty M (2000) Rank-size type distributions of the real and the virtual worlds. *INET'2000*, Yokohama, Japan, July 2000.

1. INTRODUCTION

Shiode N (2003a) A geographical interpretation of cyberspace: preliminary analysis on the scaling tendency of information spaces. In B. N. Boots, A. Okabe and R. Thomas (eds.), *Modelling Geographical Systems: Statistical and Computational Applications*, Amsterdam: Kluwers, pp. 275-293 [book chapter].

Batty M and Shiode N (2002) City size distributions in the 21st century: extending the rank size rule to measure globalisation and the diffusion of ICTs. *Cities and Regions in the 21st Century*, Newcastle, UK, September 2002.

Batty M and Shiode N (2003) Population growth dynamics in cities, countries and communication systems. In P. Longley and M. Batty (eds.), *Advanced Spatial Analysis*, Redlands, CA: ESRI Press, Chapter 16, pp. 327-344 [book chapter].

4 Interactions in Information Space

Shiode N and Kanoshima T (1999) Utilising the spatial features of cyberspace for generating a dynamic museum environment. In N. Spencer (ed.), *Proceedings for VRML'99-Fourth Symposium on the Virtual Reality Modeling Language*, New York: The Association of Computing Machinery, pp.79-84.

Kanoshima T and Shiode N (1998) Electronic interactivity for aesthetic approach to the art experience in cyberspace. In H. Thwaites (ed.), *Future Fusion: Application Realities for the Virtual Age*, Amsterdam: IOS Press, pp.210-215 [book chapter].

Shiode N (2002a) Creating 3D archaeological models in VR environment for learning and teaching resource. *Archäologie und Computer Workshop 7*, Vienna, Austria, November 2002.

Grajetzki W and Shiode N (2003) Digital Egypt: Reconstructions from Egypt on the World Wide Web. In P. Longley and M. Batty (eds.), *Advanced Spatial Analysis*, Redlands, CA: ESRI Press, Chapter 2, pp.21-40 [book chapter].

5 Information Space and Planning

Okabe A, Okunuki K, Sagara S, Kamachi T and Shiode N (1999) Virtual Ryoanji project: implementing a computer-supported collaborative working environment of a virtual temple garden, Discussion Paper Series, University of Tokyo, No.82).

Shiode N (1997a) Towards the construction of digital cities in the virtual environment. *International Symposium on City Planning*, Nagoya, Japan, September 1997.

Shiode N (1997b) Construction of a virtual city on computer network - proposal of a cellular network cyberspace. *Papers and Proceedings of the Geographic Information Systems Association of Japan* **5**: 147-150

Shiode N (1999a) Diffusion of the Internet and paradigm shift in urban planning. In P. Rizzi (ed.), *Computers in Urban Planning and Urban Management*, Milan: Franco Angeli, pp. I5:1-22 [book chapter].

Shiode N (2000c) Urban planning, information technology, and Cyberspace. *Journal of Urban Technology* 7(2): 105-126 [journal article].

Shiode N (2001a) 3D urban models: recent developments in the digital modeling of urban environments in three-dimensions. *GeoJournal* **52**(3): 263-269 [journal article].

Shiode N (2003c) Geography of Post-Accessibility Society, Invited Plenary lecture at the International Advanced Workshop on Virtual Geographic Environments and Geocollaboration, Hong Kong, December 2003.

The above list of publications consists of those relevant to this thesis and covers only a portion of my work during that period. Some of my studies on spatial analysis and modelling have been omitted from this thesis, as they did not play a significant part in the otherwise consistent structure of this thesis. For instance, the following journal articles are direct results of unsuccessful search for an analytical method for locational optimisation:

Shiode N and Okabe A (2001) A computational method for optimizing the shape and location of a polygon on a plane. *International Transactions in Operational Research* **8**(5): 547-559 [journal article].

Boots B and Shiode N (2003) Recursive Voronoi diagrams. *Environment and Planning B* **30**(1): 113-124 [journal article].

Although it is my belief that these studies have contributed to the better understanding of geo-spatial phenomena in their own ways, they were not adopted or incorporated in this instance for the sake of maintaining the coherent structure of the thesis.

CHAPTER II

GEOGRAPHY OF INFORMATION SPACE

Categorising the Spatial Structure of Information Space and Studying Their Subsets

2. GEOGRAPHY OF INFORMATION SPACE

2.1 Categorising Information Spaces

The brief review on the history of information space in the preceding chapter indicates that the development of ICTs helped the emergence of a wide variety of spaces online. Categorising the different types of spaces and identifying their functions would form the first important step towards the understanding of the spatial features of information spaces. This chapter first discusses the classification of information spaces in terms of their spatial characteristics (Section 2.1). It then examines a subset of each type of information space and interprets each of them from a geographical perspective (Sections 2.2~2.4). Each of the three datasets discussed here is an illustration of some physical embodiment of information space. There are many such subsets and their representations, but these three case studies are chosen for the purpose of illustrating the range and typology of information spaces.

2.1.1 Existing Studies on the Classification of Information Spaces

Increasingly, we hear the use of terms that combine the two elements of "information" and "space," including *IP address space*, *virtual worlds*, *Web space*, and *cyberspace*. The notion of space could be somewhat ambiguous in these instances, as some of the information spaces may have no physical entity in the real world, and whether they should be addressed as geographical places within which people can live part of their lives remains controversial.

Some argue that information-based spaces are nothing more than an archive of digital information; while some see an electronically invented Heaven or the Utopia in them (Wertheim 1999). The legacy of "the death of distance" also persists, suggesting that the efficiency of accessibility in cyberspace has virtually overcome all the problems of distant communication and interaction by providing a near-instantaneous access to the relevant information (Cairncross 2001). Most studies, however, assume that information space has a firm ground of spatiality—if perhaps governed by the rules that are different from those of the conventional geography—and they demonstrate this in various ways including the visualisation of its structure (Kitchin and Dodge 2002), quantitative analysis (Abraham 1996, Huberman and Adamic 1999, Malecki and Gorman 2001) as well as the establishment of cyberspace geography (Batty 1997, Murnion and Healey 1998, Sheppard *et al.* 1999, Wilson *et al.* 2001, Shiode 2003a).

While some novel attempts have been made towards the classification of the various information spaces, much of the existing literature tends to address only a subset of one particular type of information space, as the typology and the extent of information spaces are so diverse and volatile. Amongst the few exceptions are contributions from the related fields, where their own discipline have experienced changes in conjunction with the emergence of information spaces. For instance, Shen (1998) identified the different components of geographic space from the quantitative perspective, and classified them into the physical space, the hybrid space, and the virtual space. Also, Kaneyasu (1997) defined the contemporary cities as *media cities* from the planner's viewpoint and classified them by their relevance to information technology as

1. Cyberspace: a city or space within the media
2. Support system: a city supported by the media
3. Ubiquitous: a city or region containing the media

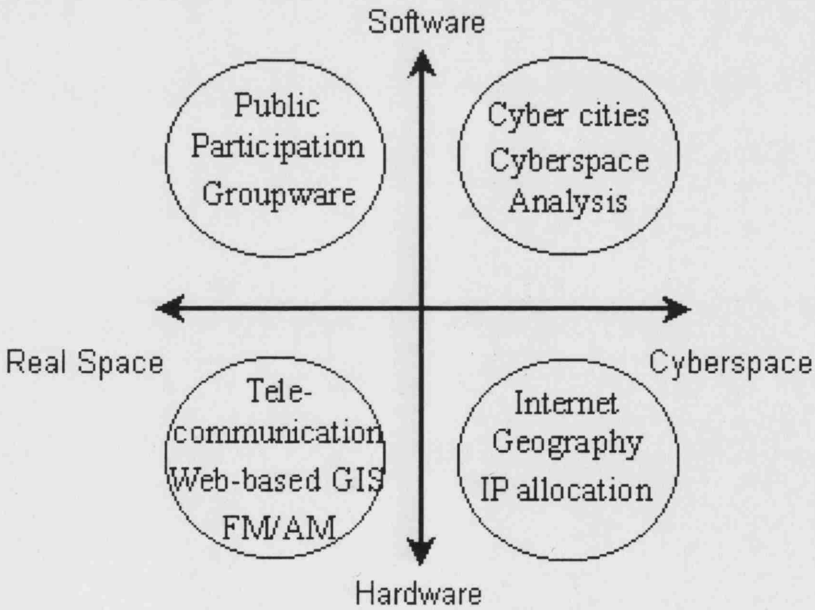

Figure 2.1.1 Interactive factors between information technology and urban planning. The nature of the space shifts from the solid, physical space of the existing cities onto the flexible, metaphorical space within the information network (Shiode 2000c).

Similarly, Shiode (2000) classified the interactive factors between information technology and urban planning into four domains (**Figure 2.1.1**). According to this study, deployment of ICTs is affecting the field of planning both in the physical world as well as in the virtual world; and it also has impact on the software (events, applications, and management) as well as on hardware (facilities, network, and infrastructures). Other efforts on the characterisation of the contemporary telecommunication-based city include Graham and Marvin's (1996) reference to various forms of "virtual cities," such as "electronic spaces," "informational city," "invisible city," and the "intelligent city".

All these efforts seem to share a similar underlying assumption, and that is to regard information space as an integral component of the existing urban society. In other words, they give emphasis on the interaction between ICT and the real space, and thereby, propose to update the classification of the spaces that have existed from the pre-Internet era and have subsequently been influenced by the development of ICTs.

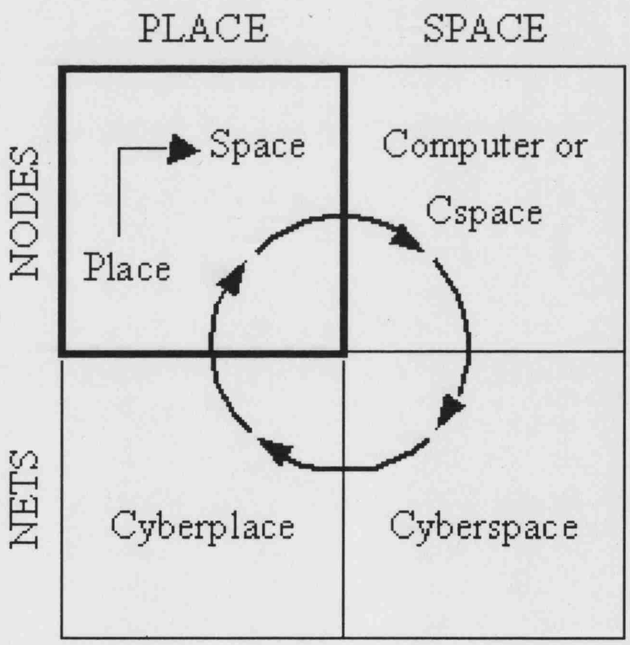

Figure 2.1.2 Virtual geography as place and space in nodes and nets (reproduced from Batty 1997).

Interpretation of the existing urban and digital spaces from the geographical perspective is important in itself, for it is indeed these "real world spaces" that we have lived our daily lives to this day. However, equally important is the understanding of the newly emerging spaces around and within the computer network in which we are increasingly spending more time and conducting more and more of our social economic activities. For instance, Batty (1997) identified three groups of spaces that lie between the users and computers as follows (**Figure 2.1.2**)

1. C-space: The space within computers
2. Cyberspace: The use of computers to communicate
3. Cyber-place: The infrastructure of the digital world.

2.1.2 Classifying Information Spaces from the Spatial Perspective

The idea of an evolutionary circle employed in **Figure 2.1.2** provides an interesting model for the evolution of information space. It suggests that the use of computers and the increase in the Internet contents promote the growth of the information space and also promotes the emergence of a new type of information space. While each space is still in their first generation of evolution, they would go through the evolutionary steps and reflect its growth onto the other spaces.

However, the series of information spaces can be also seen as a sequence of spaces that exist between the real and solid world of entity, and the most virtual, conceptual world of non-entity (Shiode 2003a). In this manner, we can distinguish the different space types with regards to their degree of realness and virtual-ness. Shiode (1999a, 1999b) identifies four types of cyberspace as follows

(a) **ICT-embedded enhanced reality**: the real world wired and embedded with ICTs to support hybrid spaces such as electronic transactions, video- conferencing and multi-player gaming environment.

(b) **Physical infra-structure**: a visible entity that reflects the conventional geography such as the physical network of fibre optics and satellites or the IP address space.

(c) **Topological info-structure**: a metaphorical space that follows its own spatial configuration of the topological connectivity such as the Web contents and hyperlinks between them.

(d) **Invented cyber-structure**: a virtual, visible space of the fictional world that maintain the notion of distance and orientation such as a 3D multi-user virtual city.

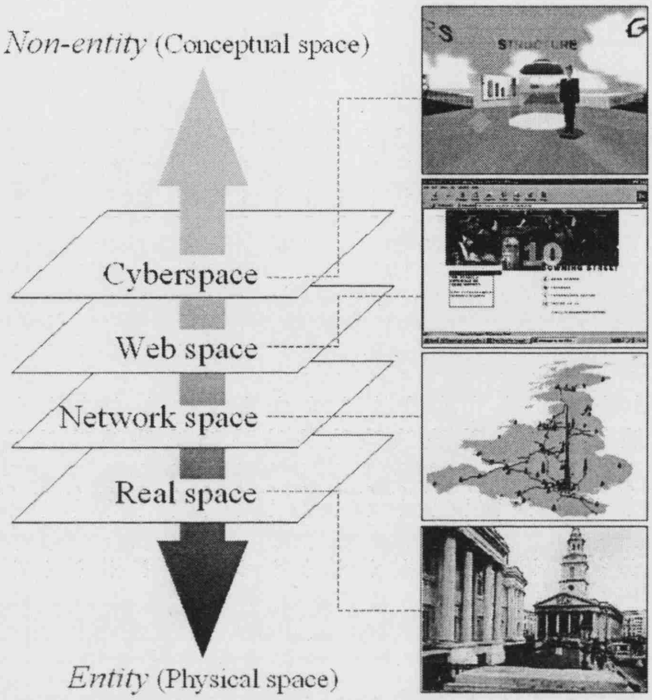

Figure 2.1.3 Layers of different types of information spaces (Shiode 2000c).

Figure 2.1.3 illustrates the typology of information spaces based on the above four groupings (Shiode 1999a). It is by no means exhaustive or conclusive but provides one interpretation of the current range of information spaces. The boundaries between each group are flexible and may be adjusted as the spaces evolve or when a new type of space emerges. These spaces comprise elements that are interdependent on those in other spaces but nonetheless can be defined and extracted as part of a single type of space. Assuming that each information space is discrete from one another, we can provide a definition and quantitative measures to help categorise them.

The following sub-sections (2.1.3~2.1.7) briefly discuss the general characteristics of information spaces including those that belong to the four groups identified in Figure 2.1.3. As aforementioned, the readers should be reminded that this classification of information spaces is based on my own interpretation of their spatial characteristics, and that there may be other ways of identifying its typology; nonetheless it does cover the whole range of information spaces. They will be revisited in Sections 2.2~2.4, where a subset of each type of information space will be studied more closely.

2.1.3 Real Space: the Conventional World and also the Wired World

The most physical end of the spatial sequence in Figure 2.1.3 is characterised by the conventional geography of the real world that gives the basis for spatial reference to all other spaces. At the same time, this world of physical places is reoriented by the development of the new information spaces, forming a feedback loop (Batty 1997). In other words, the very space that we live in is being affected by the growth of information space and also by the abundantly available computer resources that are embedded in the real space (Shiode 1999b, 2003c). In fact, researchers in the related fields have been trying to redefine the notion of the real world as they become increasingly wired and filtrated by ICTs. The impact of prevailing ICTs and the rise of ubiquitous network computing will be re-examined in a later chapter (Chapter 6).

2.1.4 Physical Network Space: The Internet and Fibre Optics

The second layer comprises the physical aspect of information spaces such as the infrastructure of the Internet, the broadband fibre-optic backbone networks and satellite networks, and the distribution of servers and clients represented by IP addresses. It consists of essentially three elements. First, there is a number of "nodes" or computer terminals through which users gain access to the computer network—these can be further classified into servers and clients. Then come the "edges" or the communication lines that connect these nodes together (e.g. fibre-optic networks, satellite networks and telephone cables). Finally, the network becomes visible and active to the general users when "traffic" or the information exchange between these nodes occurs.

The fact that these three components are embedded within the real world suggests that their attributes somewhat reflect those of the real space (Malecki and Gorman 2001), but the traffic flows observed amongst them follow a unique spatial order of their own, thus forming a unique telecommunication space (Cairncross 2001, Goodchild 2001).

The physical structuring of the network space involves some critical problems that require proper planning and analysis, but relatively few have seen this area from the spatial-analytical perspective so far (Batty and Barr 1994, Graham 1997). The notion of the computer network as a geographical space is still uncommon, and only few studies have applied locational analysis. Among these few exceptions are location analysis of Internet address ownership (Shiode and Dodge 1999a), which will be discussed in detail in Section 2.2. Also, Murnion and Healey (1998) studied on the Web traffic-flow in relation to the distance from the users; they showed that the geographical location of the users and that of the contents had certain correlation and that they had some degree of distance-decay effect. More recently, Baker (2005) proposed that, based on an empirical study of server response time, there is a physical limit to the globalization of the Internet in that the geographical distance does matter and would cause a delay effect in interaction.

2.1.5 Metaphorical Space: Topological Space of WWW

The third tier (Figure 2.1.3) consists of the metaphorical spaces, which contain multimedia contents and hyperlinks of the World-Wide Web. In essence, they depend on the physical network as identified in Section 2.1.5, but the structure of these Web spaces is in fact determined by their topological framework, thus having less relevance to the geography of the real space (Sørensen 1998, Cairncross 2001).

The Web is becoming increasingly popular ever since its dissemination in the early 1990s. Although the volatile change of its contents makes it difficult to grasp the structure of the Web, several novel attempts have been made to capture and measure this metaphorical space and its transitions. For instance, Huberman and Adamic (1999) observed that there exists a power-law between the distribution of the number of Web sites and the size of their contents. Their investigations proved that the Web is dominated by a relatively small collection of excessively large sites. In fact, roughly half of all public pages belong to the largest 25,000 sites as of 1999 (OCLC 1999), and this tendency of strong concentration towards a small number of large sites still persists (O'Neill *et al.* 2003). Moreover, Shiode and Batty (2000) proposed that the Web follows the same spatial pattern as many other social-economic distributions in that they form a power-law distribution; i.e. there exist few of the larger events and many of the smaller events. This scaling tendency of web space and that of other spaces will be discussed further in Chapter 3.

Web sites do not necessarily have a one-to-one correspondence with the IP addresses, as one server may host more than one site while several servers may function as mirror sites. Also, unlike the physical network, nodes, edges and the information traffic are all contained in the electronic space. In other words, the geographic location of servers is less significant, and the spatial order is dependent on arbitrary hyperlinks. In this sense, the Web space is a topological world, free of distance or direction, and the only decisive factor is the number of hops. Thus, it is critical to know the most connected, focal point, and to measure the connectivity of the other points from that centre. Shiode and Dodge (1999b) measured the connectivity of the global domains and visualised this space in terms of the number of links found within and amongst those domains. Their study indicates that information space of this level is independent of the spatial attributes of the real world, and that the connectivity is fundamentally a parameter of the topology of its structure (Section 2.3). In terms of a more general way-finding in the web space, Sørensen *et al.* (2001) proposes the framework of a possible tool that would improve navigability.

The recent increase in the online social-economic activities (e.g. the newly emerging economy of *e*-commerce) raises a persistent debate on whether the rise of information space has overcome the physical distance. Both arguments can be in fact valid, provided that they are looking at different types of information space; i.e. the network space and the Web space, which are strongly connected to each other, thus making it difficult to distinguish the different elements.

2.1.6 Virtual Space: Cyber Cities and Cyber Places

The last category focuses on a variety of conceptual, yet most visual type of information spaces such as 3D cyber cities and other 3D-like virtual environments. In most cases, their spatial characteristics are comparable to those of the real world. A virtual city or place consists of the following elements:

(1) the electronically reproduced urban structure,
(2) activities performed within these cities, and
(3) participants who perform activities.

These virtual spaces, on the surface, appear to hold the normal Euclidean metrics. The two distinctively different elements from the real world are

(1) the free gravity that allows users to float over the city

(2) hyperlinks to various other locations through which the user can instantly teleport (jump) to the destination.

Compared to the previous three groups, they are still relatively few in number, but this is rapidly changing. As these fully immersive, 3D environments are still evolving, we have no clear definition of what a cyber city or cyber place actually is, and major search engines would enlist anything from a flat-map representation to a 3D cyber city with the full navigation feature as "online 3D space" (Shiode 1997b). Nevertheless, their presence is being rapidly enhanced by their potentially diverse applications including urban simulation and *e*-commerce that are becoming increasingly important (Batty *et al.* 2001) (Sections 2.4 and 5.1). A comprehensive observation of applications and social implications of such virtual environments are provided by Schroeder (1996). Also, some 3D virtual worlds that hold a large number of users have been gradually developed with VRML, Web3D and other languages, many of which support multi-user interactive environments (Shiode 1997). Some studies have already pursued the utilisation of such 3D multi-user world in the planning context such that a fragment of the real world is simulated in this virtual space (Slater *et al.* 1998, Okabe *et al.* 1998, Axelsson *et al.* 2001) (Section 5.2).

Unlike the real cities, cyber cities are easily built and maintained in a server, and users can log on to them via computer network. Apart from the running cost of the server, it is virtually free from financial constraints. Once a new cyber city emerges, it develops much faster than a real city, growing almost evenly to all directions at the centre and continuously sprawling outwards (Shiode 1998, Shiode and Torrens 2003a, 2003b) (Sections 2.5 and 3.3).

2.1.7 Enhanced Reality: Chat Rooms and Embedded Entity

In addition to the above four spaces, there is a group of spaces that consists of a bit of each space. These are primarily represented in the forms of hybrid and intermediate spaces, which inherit the spatial characteristics from both the real world and cyberspace but are by and large an extension to the real space, where the ubiquitous information structure realises an electronically supported world of enhanced reality. Among the most frequently used of these spaces are Internet chat relays and various Web conferencing systems. As many such spaces are dependent on the tools in-between, each communication tool offers a proprietary environment and are occasionally incompatible with one another.

Nevertheless, they share one common spatial attribute, and that is; each of these spaces is embedded within the context of the existing entity. In other words, the users cannot be separated from the surrounding environment and, thus, these hybrid spaces will inevitably inherit the spatial attributes of the existing world to some extent.

Batty (1997) points out that "*any and every type of human interaction has some potential to be representable in cyberspace.*" This is even more so in hybrid spaces, which essentially consists of human interaction with the surrounding information space. Thus, by looking at the geographical nature of information space from the human-interaction perspective, the concept of space may depend on the way we interact with the computer resources and their network environment (Sheppard *et al.* 1999, Takeyama 2003).

In fact these spaces are none other than the real world itself (Section 2.1.4) that has been continuously enriched by adapting various communication facilities and allowing ICT resource to be embedded. As this convergence progresses towards the point where the digital technology eventually prevails over the urban society, we would have more types of media, more options of hardware, and more variation of data formats to communicate and exchange information (Mitchell 1995, 2002, Shiode 2004).

2.2 Spatial Pattern of An Internet Address Space

2.2.1 Geographical Locations in an Internet Address Space

Since the early 90s, the growth of the Internet and its services has produced significant effects in many fields (Couclelis 1996, Cairncross 1995, 2001). As popularity of the Internet increases, it becomes increasingly congested with information traffic, which in turn makes the interpretation of the Internet space crucial (Huberman and Lukose 1997). Nevertheless, the spatial issues of the Internet have yet to be focused as an objective of geographical study (Adams and Warf 1997). In principle, as it is bound by the geographical extent of the Earth's surface, geography of the Internet could be treated in a similar fashion as the conventional geography. The only apparent difference exists in the ambiguity of their geographical coordinates, for which we need to find the means to identify their postal address equivalent.

Based on an empirical investigation, this section provides an approach to defining and visualising a subset of the Internet space by ways of analysing the spatial distribution of IP addresses registered in the United Kingdom. Section 2.2.2 defines the Internet space and IP address space. This is followed by the use of GIS for analysing a non-conventional geographical space such the Internet (Section 2.2.3), review of relevant studies (Section 2.2.4), details on the data source used in this study and the processing steps taken to prepare the data (Section 2.2.5). Section 2.2.6 then explains the methodology applied in this study and the results obtained, with a focus on the IP addresses assigned to different types of organisations. We conclude with a summary of the results and discussion on future research (Section 2.2.7).

2.2.2 Internet Space and IP Addresses

The Internet is often regarded as the collective description of the services provided within the worldwide computer network such as email or the World Wide Web (WWW), but we herein use it simply as a reference to the network itself. Fundamentally, Internet space is not an infinite and unbound electronic domain, but a well defined, closed set, comprised of a finite number of elements. It is created by the addressing standard used to identify and locate computers on the network. Each computer is distinguished by a globally unique numeric code called the IP address (short for Internet Protocol address). Two types of IP addresses are in active use: IP version 4 (IPv4) and IP version 6 (IPv6). IPv4 is a unique set of 32-bit digit numbers in four blocks of three digit octets, each taking a value between 0 and 255 (for example, 128.40.59.162) (Halabi 1997). Initially deployed in January 1983, IPv4 is still by far the most popular version. However, rapid growth in Internet usage urged deployment of the IPv6 protocol in 1999. IPv6 addresses are 128-bit numbers and are conventionally expressed using hexadecimal strings (for example, 1080:0:0:0:8:800:200C:417A) (IANA 2005).

IP addresses are the fundamental forms of computer addressing used to determine a "location" within Internet space, enabling computers to communicate with each other. The IP address defines a massive spatial array, allowing sufficient allocation for all foreseeable network resources including our PCs, handheld devices, and other network-based appliances. In practice, however, the actual usable Internet address space is smaller than the physical maximum because of the way it has been partitioned and allocated (Semeria 1998).

IP addresses can be compared, in principle, to postcodes that are used in the real world to identify locations for the delivery of letters and parcels. Postcodes define a distinct and widely used form of spatial referencing (Raper *et al.* 1992). In one respect, IP addresses are the Internet equivalent of the postal address, allowing parcels of data, known as packets, to be delivered to the correct computer. IP addresses are usually allocated in large blocks. Taking the postcode analogy further, blocks of IP addresses can be thought of as forming chunks of valuable "real-estate" on the Internet onto which computers can be "built."

2.2.3 GIS and Internet Geography

GIS is renowned for its ability to visualise, analyse and model geographical data, applying quantitative geographical methods within a digital environment (Longley and Batty 1996). GIS relates to the Internet and its geography in two aspects. One is the utilisation of the WWW as a networked GIS delivery media. This is known as "Internet-GIS" and is becoming increasingly popular with vendors, developers and users (Plewe 1997, Wang *et al.* 2003).

The other aspect is to define the Internet as a new objective of geographical analysis in conjunction with GIS. Despite the growth of the Internet and its increasing significance, little has been studied on Internet space from this perspective. This would not only encourage a complex structure of Internet space and lack of comprehension towards the Internet domain, but may also hinder the sound development and maintenance of the entire Internet service.

Here, we utilise GIS techniques to better understand Internet space. In particular, we map Internet space onto the real, geographical space by examining the spatial distribution of IP address ownership within the United Kingdom and referring to the location of each point with the corresponding postcode zone. It requires both visualisation capability as well as the analytical functions of GIS to explore the spatial distribution pattern of the 44 million IP addresses. For this purpose, we introduce spatial analysis functions of GIS to investigate the geography of the Internet.

2.2.4 Relevant Research

Whether it is a detailed examination of the geography of the Internet or investigation into IP address space from a geographical perspective, there has been little academic research that actually explored Internet space. There are several interesting studies that cover the Internet geography on a global scale, working with data readily available at the national level (Batty and Barr 1994, ITU 1997, ISC 2004).

In fact, there are few studies examining the geographical patterns on sub-national scales. A notable exception is the work of Moss and Townsend, Taub Urban Research Center, New York University, who analysed the geography of Internet domain name ownership in the United States (Moss and Townsend 1997). Similarly, Matrix Information and Directory Services[2] (1999) has mapped Internet hosts and domain names for many countries around the world. Back in 1997, MIDS also produced density surface maps of Internet hosts in the United States.

Other visualisation efforts on the Internet are mainly put into mapping cyberspace and network traffic (Dodge 1998). For instance, Luc Girardin's "cyberspace geography visualisation" system aims to construct a metaphorical map of the WWW space to help people find their way (Girardin 1996). Similarly, the WEBSOM project creates interactive, multi-scale document maps of Usenet newsgroups (NNRC 1997). Internet traffic has also been subject to geographic exploration, especially for real-time visualisation of WWW traffic (Cox and Patterson 1992, Lamm *et al.* 1996). Wang *et al.* (2003) mapped the geographical coordinates of a set of Internet servers using GIS and proposed that the death of distance hypothesis (Cairncross 2001) would not hold after

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[2] Matrix Information & Directory Services, Inc. has ceased to provide its consulting service in late 1999; but its mapping services have been succeed by Netcraft, ISC, and the alike, as discussed in Section 1.2.2.

all. Several books have been also published in the light of new geography of information and the Internet, if perhaps focused on the growth of the Internet itself (Kotkin 2000, Kellerman 2002).

2.2.5 Data Source and Processing

When this case study was conducted in late 1997, the Internet was still in the middle of its transitional period of commercialisation and globalisation. It was undergoing a rapid transition from a network that had been effectively run by the U.S. government and academia to a global communications medium. Consequently, the ownership and management of Internet standards and protocols, such as IP address space and domain names, were sources of intensive debate (Conrad 1996, Kahin and Keller 1997, Shaw 1997). As the management of Internet space remains controversial, the comprehension of Internet geography was important then and is becoming ever more important.

IP Space Registration

In practical terms, the global IP address space is maintained by the Internet Assigned Number Authority (IANA; *www.iana.org/*), who in turn delegates large blocks of addresses to regional Internet registries (RIRs) to administer (Foster *et al.* 1997). There are three regional registries responsible for different geographical areas: APNIC (Asia Pacific Network Information Center; *www.apnic.net*), ARIN (American Registry for Internet Numbers; *www.arin.net*), LACNIC (Regional Latin-American and Caribbean IP Address Registry; *lacnic.net/en/index.html*), and RIPE NCC (Réseaux IP Européens; *www.ripe.net*). For instance, RIPE NCC covers Europe, the Middle East, Central Asia, and African countries located north of the equator. Individual organisations and companies in need of an IP address make requests to the appropriate regional or local registries for the required size range of IP address space. Apart from a small registration fee, IP space is allocated free to the organisations for their exclusive use (Hubbard 1996). In the early 1990s, they had to prove a genuine need for the Internet "real-estate," as IP space was becoming a scarce resource, and there was a fear that all combinations would have been exhausted (Huston 1994). The deployment of IPv6 expanded the amount of available space to near infinite, but the request for IP address blocks still needs to be supported by the necessity for genuine use (IANA 2005).

Data Source Information

As detailed above, RIPE NCC is responsible for the allocation and management of IP address space in Europe and the surrounding countries. The RIPE network coordination centre, based in Amsterdam, maintains a large database of operational Internet information known as the "RIPE Network Management Database" which contains details on allocation (Magee 1997). In March 1997, Shiode and Dodge (1999a) obtained a copy of the allocation data from the RIPE NCC ftp site with their permission (Dodge and Shiode 1998, Shiode and Dodge 1999a). The data included lists of all the companies and organisations in Europe to which allocations have been made, along with, in most cases, details of two designated contact people in the organisation concerned. A complete postal address was given for the majority of these contact people which was subsequently used to geographically locate the IP space allocations. For those with an incomplete address, the postcode was obtained from the street name, if any, or from the name of the organisation.

These designated organisations and people were regarded as the *de facto* "landowners" of that block of IP address space and their postal addresses were used as the reference point in the geographical space where the IP addresses are located. In order to protect privacy of the individuals and organisations concerned, all personal information was removed, immediately after the designated postal address had been used to give each IP allocation record a geographic co-ordinate (Shiode and Dodge 1999a).

Limitations of IP Address Data

There are several limitations with these IP address data. Firstly, the RIPE database is maintained for the purposes of operational management of the Internet and, thus, may not be entirely accurate or suitable for the purpose of geographical analysis. However, this was and still remains as the only available source of information on the ownership and distribution of IP addresses. Besides, its overall accuracy was quite satisfactory

(99.6% address matching was achieved after the initial data processing), including that of the postal address we used to identify the locations.

Secondly, the analysis conducted in this case study was based on the spatial distribution of the "ownership" of IP address space. This may not be necessarily the same as where the space is actually used, i.e. where the network computers are physically located and linked to the Internet. In fact, some organisations may have an entire block of IP addresses registered at their headquarters and distributed them online to different branches. There is no direct solution for this problem; however, many of the nation-wide organisations use Intranets to connect their branches and register a relatively small number of IP addresses that are assigned to their Internet gateway machines at their head office or network support division.

Finally, the result of this case study presents the geographical distribution of IP address ownership at a single point in time. When interpreting the results, it should be noted that, with the rapid growth of the Internet, the IP address space is likely to be subject to constant change. The most recent distribution pattern of IP address ownership can be portrayed only by a constant effort of mapping the latest dataset onto the geographical space; thus requiring a dedicated project on a time-series analysis. Unfortunately, rapid growth of the Internet makes this practically impossible to carry out in person, and this case study thus remains as a depiction of the IP address ownership map in the UK at a single time point. Perhaps a follow-up survey can be achieved through randomly selecting a small sample set of the RIPE data.

IP Address Space in the United Kingdom

The IP address space registry contained 10,660 records of IP space blocks allocated to organisations and companies for use in the United Kingdom as of March 1997. This yielded to a total of 44,673,268 unique IP addresses that represented about one percent of the total global IP address space. The ownership of these 44.7 million IP addresses was then pin-pointed to a geographical location with the postal address details of their "landowners." After several processes of data cleaning, 99.6% of the IP address space was matched to a geographical location. Interestingly, about one percent of this address space was actually registered to owners located outside the UK, in some twenty-five different countries.

Table 2.2.1 Breakdown of the IP addresses by category (Shiode and Dodge 1999a).

Category	Number of IP Blocks	IP Address Size (mil.)	Percentile in Total Size (%)
Commercial	8176	34228315	76.73
Government	1065	2366768	5.31
Academic and non-profit	1419	8012650	17.96
Total	10660	44607733	100.00

The UK IP address space was categorised into three groups based on the nature of the organisation. These were (a) commercial, (b) government, and (c) academic and non-profit organisations. The breakdown of IP address space by these groups was 77%, 5% and 18%, respectively, as shown in Table 2.2.1.

2.2.6 Analysis of the IP Address Density Patterns

The results of the preliminary analysis of spatial patterns of Internet space in the UK were displayed on a geographical framework using dot distribution (Figure 2.2.1 overleaf) and continuous density maps (Figure 2.2.2). For convenience, the maps show a subset of the UK data covering only Britain, excluding 283 records (674,645 IP addresses) for Northern Ireland, the Channel Islands, the Isle of Man and non-UK registered IP address allocations. In other words, a total of 10,183 allocation records, representing some 43.85 million IP addresses, were used to create the two maps (Figures 2.2.1 and 2.2.2).

<u>Distribution of the IP Address Blocks and Spaces in the United Kingdom</u>

The locations of the 10,183 allocation records are mapped in Figure 2.2.1 with each dot representing one record. There is a wide spatial distribution of dots, covering all parts of Britain from Penzance in Cornwall up to the Shetland Islands. As expected, the

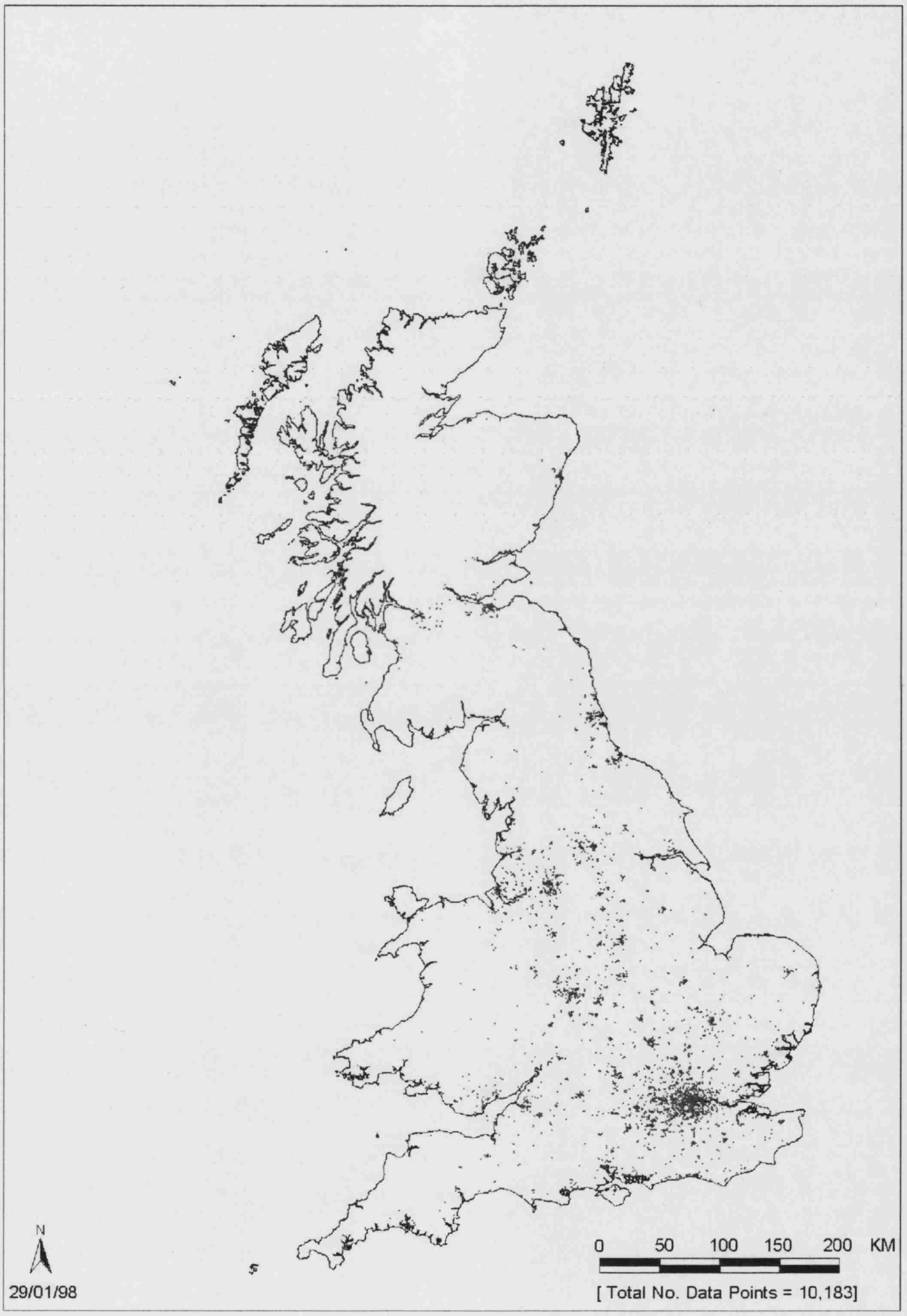


Figure 2.2.1 A dot distribution map of IP address blocks allocated in the United Kingdom as of March 1997 (Shiode and Dodge 1999a).

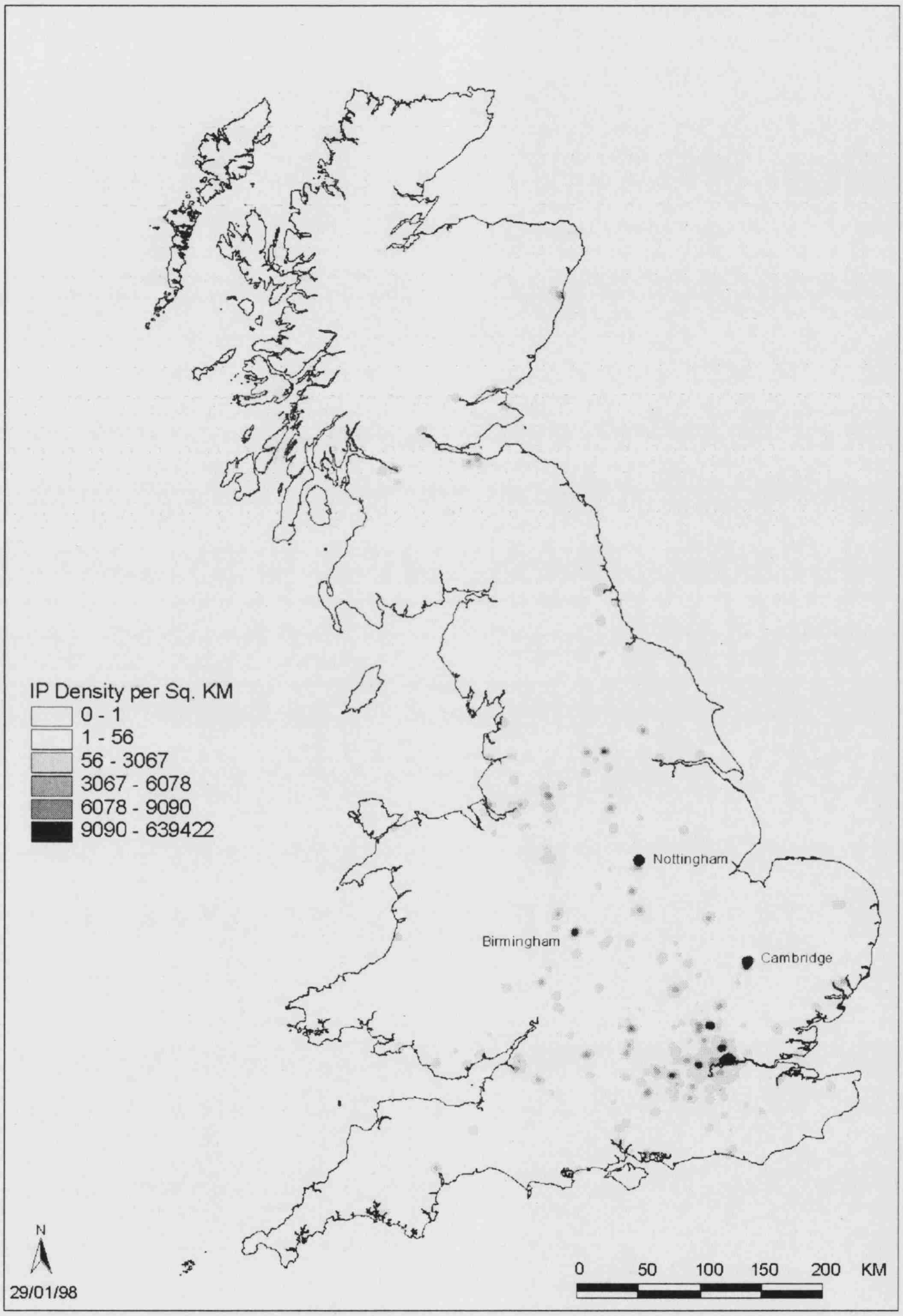


Figure 2.2.2 The IP address density surface covering the United Kingdom as of March 1997 (Shiode and Dodge 1999a).

majority of the allocation records are located in the major cities. Central London clearly stands out, with a very dense cluster of data points, along with the towns in London's hinterland to the west towards Heathrow and north towards Luton. Other notable concentrations include Birmingham, Manchester and Newcastle.

Each data point in Figure 2.2.1 represents widely varying sizes of IP address blocks. This variation can be visualised in a proportionate manner as shown in Figure 2.2.2, where the continuous density surface was formed by the actual number of IP addresses assigned to each point record. In other words, Figure 2.2.2 shows the IP address density surface for the whole of the Britain based on the 43.85 million IP addresses rather than the allocation records. The surface is "spotty" in appearance, with much of the country effectively being flat except for a few spikes of high IP address density observed in a few urban centres. The highest densities, represented by black shade in Figure 2.2.2, are in the range of 9090 to 639,422 IP addresses per square kilometre. A concentration of high density IP space spikes is evident in and around London. Additional spikes are found in Nottingham and Cambridge with IP address densities of 639,000 and 82,000 per square kilometre, respectively. The high IP density in Nottingham is caused by one large block of address space allocated to an Internet service provider (ISP). Cambridge is noted for a high concentration of computing and research- orientated companies, as well as the university itself. London enjoys a powerful position as the pre-eminent centre for corporate and government headquarters functions.

From Figure 2.2.2 we conclude that the majority of IP address space is owned by organisations and companies located in the Midlands and Southern Britain and particularly in London and its hinterland towns.

<u>Distribution of IP Address in Southern England and Greater London Area</u>

Figure 2.2.3 shows the density surface for the Midlands and southern England. County boundaries and motorways are also shown to give context. At this large scale, the "spotty" density surface is even more evident. The major peaks of high densities, outside the London region, are in Cambridge, Birmingham and Oxford. Bristol and Portsmouth exhibit rather modest values of density for its population.

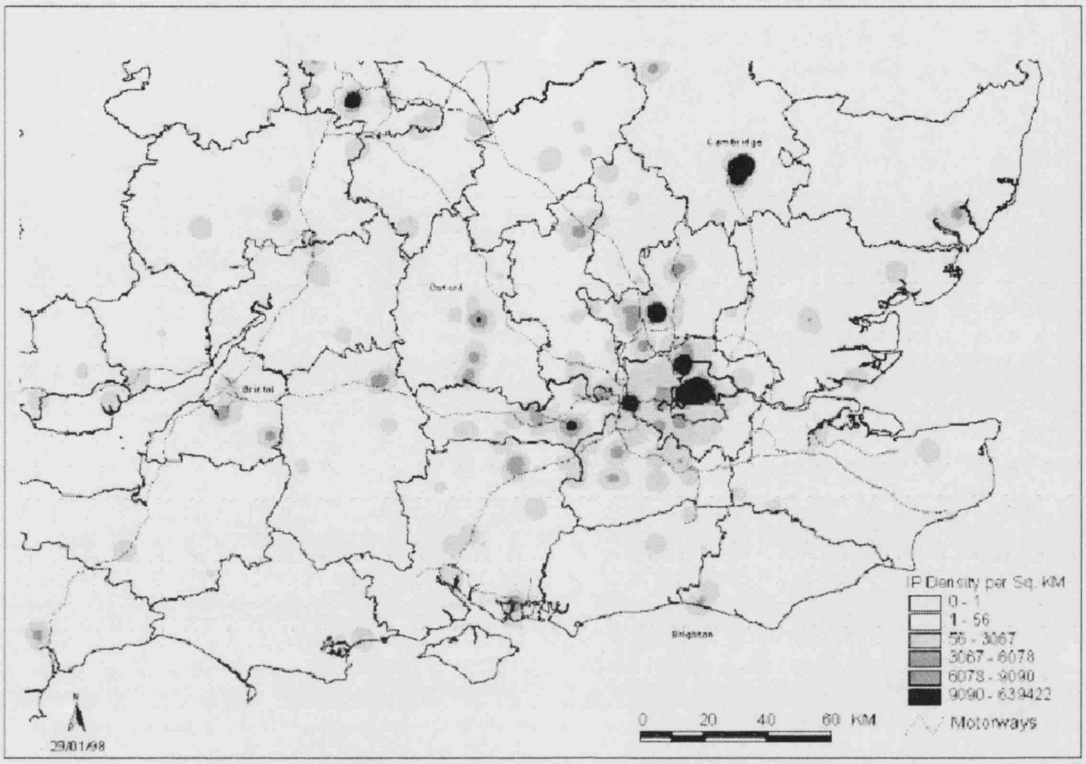


Figure 2.2.3 IP address density surface of Southern England (Shiode and Dodge 1999a).

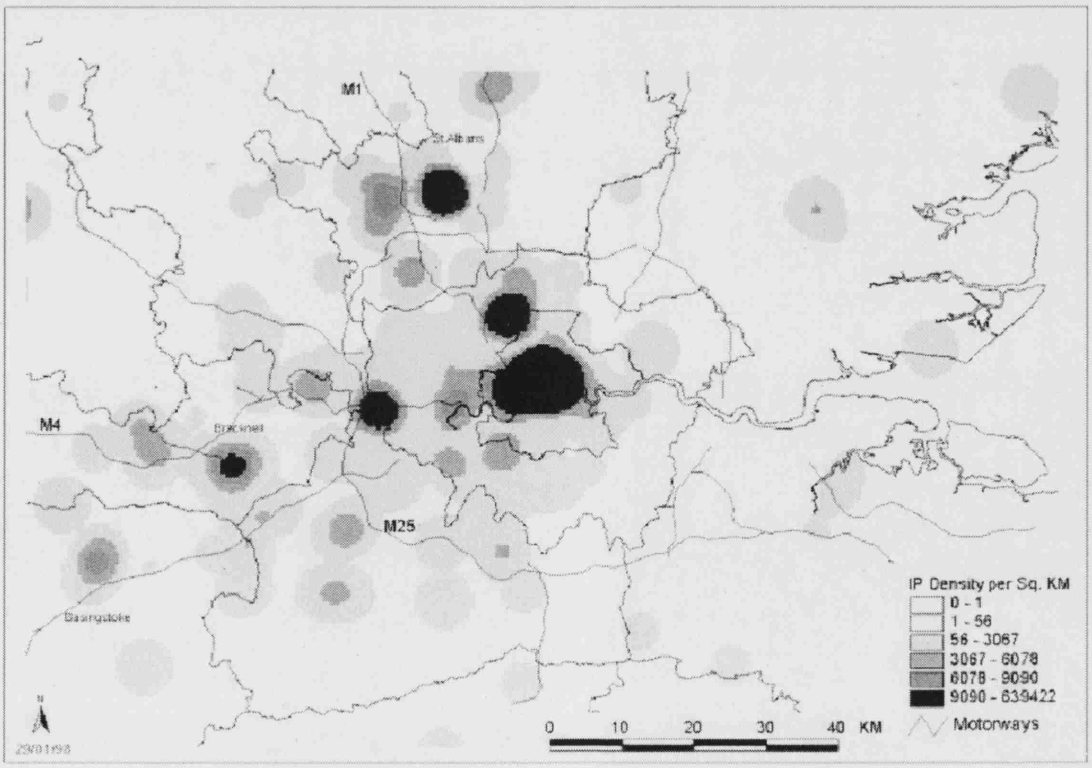


Figure 2.2.4 IP address density surface in Greater London (Shiode and Dodge 1999a).

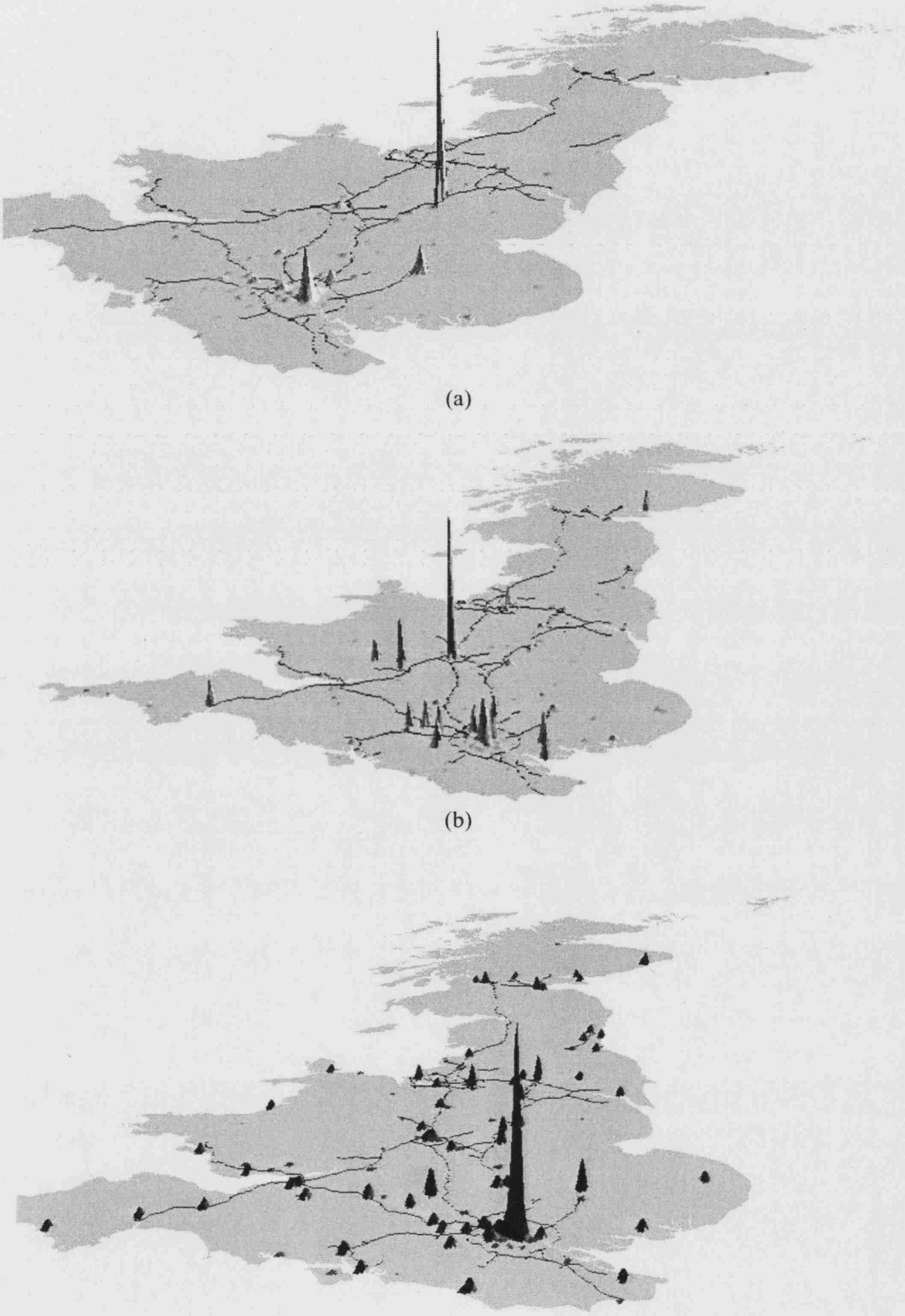
Figure 2.2.4 provides a close-up view of Greater London and its hinterland revealing the complexity of IP address density patterns in this region. It clearly indicates the stronger concentration of IP addresses on the western side of London compared to those in the east. Central London clearly stands out, with a large, oblong-shaped zone of a significant density, peaking at 154,500 per square kilometre (Figure 2.2.4). This zone covers the entire City area across to the West-end. There are two other notable high density areas inside the boundaries of Greater London. The one to the west of central London is the area around Heathrow airport with an IP address density of 18,600 per square kilometre. The other dense batch in north London, with a peak density of 22,900, is due in part to the headquarters of a major ISP.

Looking at the immediate hinterland surrounding London itself, many of its smaller satellite towns have high IP address densities. These satellite towns have experienced considerable growth in computer-related industries in the last ten to fifteen years. Heading north out of London, along the M1 motorway, high densities are apparent in Watford, Hemel Hampstead and particularly St. Albans, with 33,800 IP addresses per square kilometre. St. Albans's high IP address densities are largely caused by the headquarters of the Internet operations for a major telecommunications company. Following the M4 motorway west out of London, several other "hot-spots" can be observed. These are the towns of Slough, Reading and particularly Bracknell, with 11,900 IP address per square kilometre.

IP Address Density Maps of Different Organisations

Figures 2.2.5(a)~(c) respectively show IP address surfaces as 3D isometric maps for three different groups: commercial, government, and academic and non-profit organisations. The maps show sharp peaks in their surfaces, with high concentrations in relatively few locations. Also shown is the motorway network to provide some cartographic context. The maps were produced in a 3D visualisation extension to a conventional two-dimensional desktop GIS[3], which allows its users to view the 3D map from any position. As mentioned, the breakdown of these groups was 77%, 5% and 18%,

[3] Figures 2.2.5(a)~(c) were produced with the 3D Analyst extension tool in the ArcGIS environment.



(a)

(b)

(c)

Figure 2.2.5 3D Density surface for the IP address blocks of (a) commercial organisations, (b) government organisations, and (c) academic and non-profit organisations (Shiode and Dodge 1999a).

respectively. This implies the rapid development and investment by the commercial firms after the commercialisation of the Internet in the mid 1990s. Although they differ in the share of IP addresses they hold, each group has its distinctive role and is by no means negligible, and, interestingly, they exhibit distinctly different patterns.

Figure 2.2.5(a) shows the 3D density surface of IP address for commercial organisations. Although we assume the predominant position of London, it actually reveals that one ISP service in Nottingham exceeds the total IP address density of London area by far. Figure 2.2.5(b) shows the density surface for government organisations. The large peak in the centre shows that Birmingham holds many more IP addresses for governmental use than other densely distributed areas including the Greater London, Edinburgh and Exeter. Finally, Figure 2.2.5(c) shows the IP address density surface for academic and non-profit organisations. It displays the dispersed characteristics of academic organisations when compared to Figures 2.2.5(a) and (b).

2.2.7 Summary of Findings on the UK IP Address Blocks

This section defined the geography of Internet space and analysed its subset by measuring the density of IP addresses in the United Kingdom as of 1997. The majority of the UK's Internet space was then owned in a few urban centres. These included central London and the surrounding satellite towns, along with Nottingham, Cambridge and Birmingham. The spatial variations in the ownership of 44 million Internet addresses were visualised by creating a continuous density surface. The IP address distribution patterns for different groups of organisations had a remarkably different pattern from one another (Figures 2.2.5(a)~(c)).

Unfortunately, the original data obtained from RIPE were not designed for such analysis, thence requiring a considerable amount of processing. The results obtained in this study remain at the exploratory stage and would require a significant effort to pursue a time-series analysis (Best and Krueger 2004), which perhaps would be worth one doctoral research alone. the data used here are discussed more in detail in a later section (Chapter 3) with respect to their scaling tendency and also in conjunction with the existing socio-economic geography of Britain and the spatial patterns of the Internet "real-estate" ownership which, again, is achieved through the use of GIS.

2.3 Geography of Web Space and Web Metrics

2.3.1 The Web Space as a Geographical Entity

The World-Wide Web is a globally distributed hypertext system (Berners-Lee *et al.* 1994), which has grown tremendously in size since the 1990s (Bharat and Broder 1998, Lawrence and Giles 1998, Net Factual 2003). The scale and complexity of its structure seem to be increasing exponentially, and it appears that the Web has become one large cluster of entangled *cobweb* with little known about its structure (Barabási 2003). We do not know if there is a particular distribution pattern of information and hyperlinks of the Web across the virtual space. Nor do we know if the Web has a *central location* that functions as a hub. All this makes it difficult to understand the overall structure or even just to browse through the site of one's own interest, which is known as *net surfing*. Metaphorically speaking, it is similar to surfing in a sea where the depth, the current, the wave and the distance from the coast are hardly known. Applying spatial analysis techniques and GIS technologies may cast some more light on estimating the "depth," the "current" and the "distance" of the Web. Understanding and mapping the structure of the Web would be useful for those creating new Web sites and those who try to use the Web for fun or for work, especially as it has increasingly become the focal medium for shopping, commerce and myriad of other information services.

This section presents results from a case study on the analysis of the structure of the Web hyperlink using methodologies from geography and network analysis, in particular how one can determine the central location of the Web based on the mini-sum criterion. The underlying assumption is that the number of hyperlinks between any two Web sites can be used as a measure of relative accessibility from each domain to the other. In this light, this study proposes that the number of links between two Web sites is inversely proportional to the virtual distance between the two (Shiode and Dodge 1999b). In other words, the more links there are between them, the closer together in virtual distance terms the sites would be. This accessibility can be also thought of as a measure for the degree of virtual centrality. If the average of the minimum access distance to a particular site from the others is smaller than that of the other sites, we may assume that this site is the most strongly connected location in the network, thus acting as the central location of the Web or the median that satisfies the mini-sum criterion in the graph theory.

2.3.2 Relevant Research on the Geography of the Web Space

When this case study was carried out in 1998, there was already a growing body of work analysing the content and structure of the World-Wide Web (Shiode and Dodge 1999b). Much of them were studied from the computer science perspective, with the aim to improve searching and navigation of the Web space. This series of literature can be identified as that of *Web characterisation* (Pitkow 1998). A similar project was lead by the World Wide Web Consortium on Web characterization (*www.w3.org/WCA/*). Bray (1996) carried out a pioneering work in analysing Web structures and characteristics (like average size of Web page and site) of a snap-shot of the Web from late 1995 which comprised some eleven million pages.

In terms of searching, the use of hyperlink structures proved to be a powerful aid in identifying relevant Web pages from key word searches (Marchiori 1997, Spertus 1997). In particular, Google search engine (http://www.google.com/), originally developed by researchers at Stanford University, marks the prime example of a commercial application for hyperlink information archiving as a factor in relevancy ranking of results. Other work tried to identify *hub* pages for a given topic using hyperlinks structure (Gibson *et al.* 1998, Terveen and Hill 1998), with the underlying assumption that it is in our human nature to establish link(s) to the sites we find most interesting and useful.

Also relevant to this study is the work known as bibliometrics using co-citation analysis which has been pioneered by researchers in the information and library science disciplines (Garfield 1970, White and McCain 1998a, 1998b, Barabási 2003). Citation indexes of academic journals are used to analyse the structure of scientific ideas and identity key topics and researchers. Results from bibliometric analysis have also been visualised using abstract maps (McCain 1990, Small and Garfield 1985). For instance, Chen and Carr (1999) applied co-citation analysis to a corpus of conference proceedings and visualised the results on the Web in a 3D virtual environment. Larson (1996) actually employed co-citation on the hyperlinks between a small sample of related Web sites on GIS, earth science and remote sensing.

Another useful analytical concept is that of the *small world* phenomena whereby people are assumed to be closely interconnected by social networks so that any two people chosen at random are related or acquainted through a social chain of six or less steps (Kochen 1989, Barabási 2003, Watts 2003). This concept was initially developed by sociologist and political scientists and was popularised as the "six degrees of separation" and then made famous on the Web as the "six degrees of Kevin Bacon" game (Collins and Chow 1998, Watts 2003). Adamic (2000) has applied this idea to Web hyperlink structure and suggested that any two web pages chosen at random on the Web would be separated by 19 clicks of hyperlinks, or that the Web had a "19 degrees of separation." This section extends on this idea of the small world approach and it incorporates virtual distance on the global domain database obtained from AltaVista, which was by far the most predominant commercial search engine data at the time when this case study was conducted (Sullivan 1999).

There has been surprisingly little work from geographers analysing the Web. Most of the work, although valuable, has been limited to detailed examination of small samples of Web site (Alderman and Good 1997, Brunn and Cottle 1997, Jackson and Purcell 1997, Pritchard 1999). Notable work has been done by Norris (1998, 1999) who looked at the representation of third world nations in Web search engine database.

2.3.3 Measuring the Virtual Distance of the Global Domain Space

Data Collection and Preparation

To explain the approach adopted in this study, let us begin with a simple subset of the Web that consists of four main second-level domains for the United Kingdom. Table 2.3.1 (overleaf) shows the number of Web pages that matched queries on AltaVista search engine[4] (*www.altavista.com*) in July 1998. In the following, the number of pages is taken as a representative value for the size of each domain and is referred to as the Web domain size or simply the size.

It is clear that over 90% of the UK-based (*.uk*) web pages belong to either one of the four domains: *co.uk* (commercial), *ac.uk* (academic), *org.uk* (organisation) and *gov.uk*

[4] Whether the database of the AltaVista search engine actually covers the majority of the Web sites or not remains an open question (Lawrence and Giles 1998). Similarly, we do not know if their data are free from all the bias. Nevertheless, it was considered to be the most comprehensive publicly available index of the Web at the time of the study (Sullivan 1999) that contained over 150 million pages (as of May 1999). We assume that the data from AltaVista reflect the actual state of Web well and that they can be used as a basis for deducting the general tendency of the Web distribution.

Table 2.3.1 Size of the domains in the United Kingdom Web space.

Domain	Number of pages	Percentage (%)
co.uk	3,102,489	54.2
ac.uk	1,658,304	29.0
org.uk	262,116	4.6
gov.uk	164,057	2.8
Others	539,243	9.4
Total	5,726,209	100.0

(Data source: AltaVista search engine - 10 July 1998) (Shiode and Dodge 1999b).

Table 2.3.2 Link matrix between the major domains in the United Kingdom.

To / From	co.uk	ac.uk	org.uk	gov.uk	Total
co.uk	1404131	64713	27210	26361	1522415
ac.uk	68393	658652	17447	9467	753959
org.uk	33506	11600	64675	3932	113713
gov.uk	12203	2167	2237	44014	60621
total	1518235	737133	111573	83777	2450708

(Data Source: AltaVista search engine - 10 July 1998) (Shiode and Dodge 1999b).

(government). Others less frequently used domains included *ltd.uk* (limited companies), *sch.uk* (school) and *nhs.uk* (National Health Service). However, for the sake of simplicity, only the four major domains are used in the following analysis.

Table 2.3.2 shows the hyperlink matrix between the sub-domains. Each cell represents the number of links from the outgoing site on the left column to the incoming site on the top row. Naturally, cells on the diagonal line from the top left to the bottom right show the number of internal links; e.g. a link within a university site referring to another college.

These hyperlink data were also collected through the AltaVista search engine. We used a script to generate multiple queries, 16 separate queries in this case, and counted the number of hyperlinks between each sub-domain by applying the query syntax,

+url:<sub-domain1>.uk +link:<sub-domain2>.uk

In general, there is small difference in the number of incoming and outgoing links of each pair of domains, and internal links accounting for the majority (IBM Almaden 2000). The incoming and outgoing links can be thus combined together to form a triangular matrix of nondirectional connectivity (Table 2.3.3).

Table 2.3.3 Triangular matrix of non-directional connectivity among the major UK domains (Shiode and Dodge 1999b).

to / from	co.uk	ac.uk	org.uk	gov.uk
co.uk	1404131			
ac.uk	133106	658652		
org.uk	60716	29047	64675	
gov.uk	38564	11634	6169	44014

It is natural to think that *the more links there are, the closer the two sub-domains are* (Shiode and Dodge 1999b). Thus, we introduce the notion of relative distance and suppose that the distance D_{ij} between an arbitrary pair of sub-domains (nodes) i and j is inversely proportional to their number of links l_{ij} between them (connectivity). In particular,

$$D_{ij} \propto l_{ij}^{-1} \left(i \neq j, i, j \subset N \right) \tag{2.3.1}$$

where D_{ij} and l_{ij} are the distance and the connectivity between i, j, respectively.

The data also needs to be standardised so as to remove the possible effect of domain size. The unbiased distance δ_{ij} is defined as inversely proportional to the multiple of l_{ij} and the mode sizes S_i and S_j.

$$\hat{D}_{ij} = \frac{D_{ij}}{\sqrt{s_i s_j}} \tag{2.3.2}$$

Table 2.3.4 overleaf shows the result of standardisation where each cell shows the distance between each node pair.

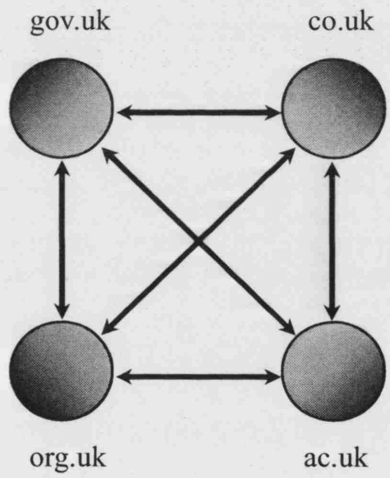
Table 2.3.4 Virtual distance between the major domains of the United Kingdom (Shiode and Dodge 1999b).

to / from	co.uk	ac.uk	org.uk	gov.uk
co.uk	0			
ac.uk	2587.16	0		
org.uk	7466.20	6682.57	0	
gov.uk	7576.65	2285.73	14345.86	0

Calculating the Shortest Path

Using the standardised distance, or the number of links weighted by the size, the mini-sum of each node can be determined. In other words, we calculate the minimum access distance of each node from the other node, obtain the average value for each node and compare it to those of the other nodes to determine the central node; i.e. the node that is most well connected to the rest of the network.

In order to evaluate the mini-sum performance of each node and to calculate the shortest path between each pair, the ordinary Dijkstra algorithm was used[5].



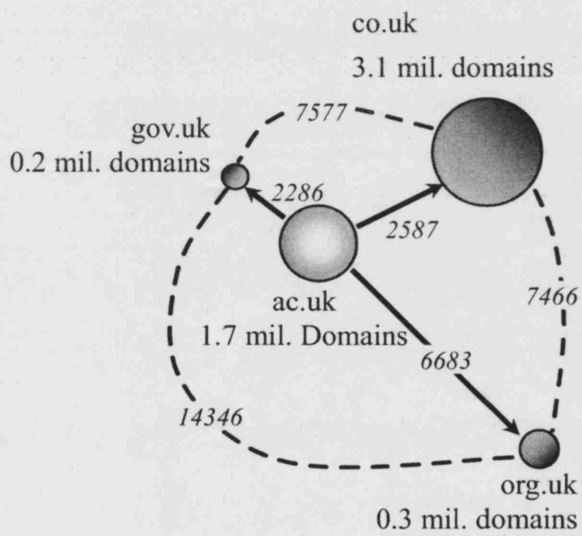


Figure 2.3.1 Visualisation of the connectivity among the four major UK sub-domains; (a) a schematic diagram showing the topological relationship, (b) a 2D map of the UK sub-domain space that shows the size of each domain as well as the relative distance among the four groups (Shiode 2000b).

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[5] This essentially takes the computational complexity of order n^2, and it is preferable to use more efficient methods when processing a hyperlink network of a larger scale. For instance, we can improve the performance by applying R-heap method and storing the temporary labels in 1+[log *nC*] buckets rather than a single bucket as in our program. Alternatively, as the Web hyperlink space appears to be well connected with non-negative edges, we may produce an adjacent matrix and express the priority queue with a non-ordered array as in Prim's algorithm of minimum spanning tree. (Further details can be found in operations research and network flow literatures, for example, Nemhauser, *et al*. 1989.)

Through our shortest path program, the following mini-sum values were obtained for each domain: *co.uk*: 14925; *ac.uk*: 11554; *org.uk*: 21724 and *gov.uk*: 14733. It is apparent that ac.uk has the smallest mini-sum value and is, therefore, the most accessible domain amongst the four.

Assuming that it serves as the centre of the UK Web space, we place *ac.uk* in the middle and map the other domains in proportion to the distance from ac.uk. Visualising this result on a two-dimensional map would require another variable to uniquely fix the location of the nodes that represent each sub-domain (Figure 2.3.1). If the set has an actual geographic distribution in the real world, we can utilise the existing maps and produce a cartogram. However, in this example, the objects are the UK sub-domains that scatter all over the country; thus we need to generate a map under a different concept. One way is to use an abstract space which is employed later (Section 2.3.5).

2.3.4 Analysis of the Global Domain

Following on from the previous example, the connectivity of the Web in terms of global hyperlinks between different countries was examined, and this was represented by Internet domains. The most accessible domain of all could be tentatively called as the most "central" region of the Web; which may be visualised as the map of web connectivity overplayed on top of a conventional earth map as well as in a more abstract form by using a solar-system type map.

<u>Statistics of the Source Data</u>

Again, using the AltaVista search engine, the total number of Web pages for the 180 major top-level Internet domains were obtained, which represent a nation or a large set of organisations of similar characters (e.g. *gov* as in U.S. government bodies). The domain size ranged from the super-scales of com (commercial): 48,284,554 hits and *net* (network): 7,467,435 hits; down to small country domains such as *cg* (Congo): 109 hits and *tp* (East Timor): 106 (a full listing of the data is given in Table 2.3.6). Figure 2.3.2(a) shows the histogram of the domain sizes where many of them fall within the range of 5,000 to 10,000 pages. Figure 2.3.2(b) shows the actual breakdown of the histogram in Figure 2.3.2(a).

The number of hyperlinks between 180 domains was also investigated. Within the 16,111 possible combinations, a total of 76,735,152 links were observed of which 16.1% (12,318,346 links) were found between *com* and *net* (Figure 2.3.3). Also, approximately 20% of these node pairs (3,116 links) were not directly connected to each other. For computational purposes, we treated these edges as very poorly connected links; assigning the link width of 0.001 so that, in turn, they take a large figure as the distance between each other.

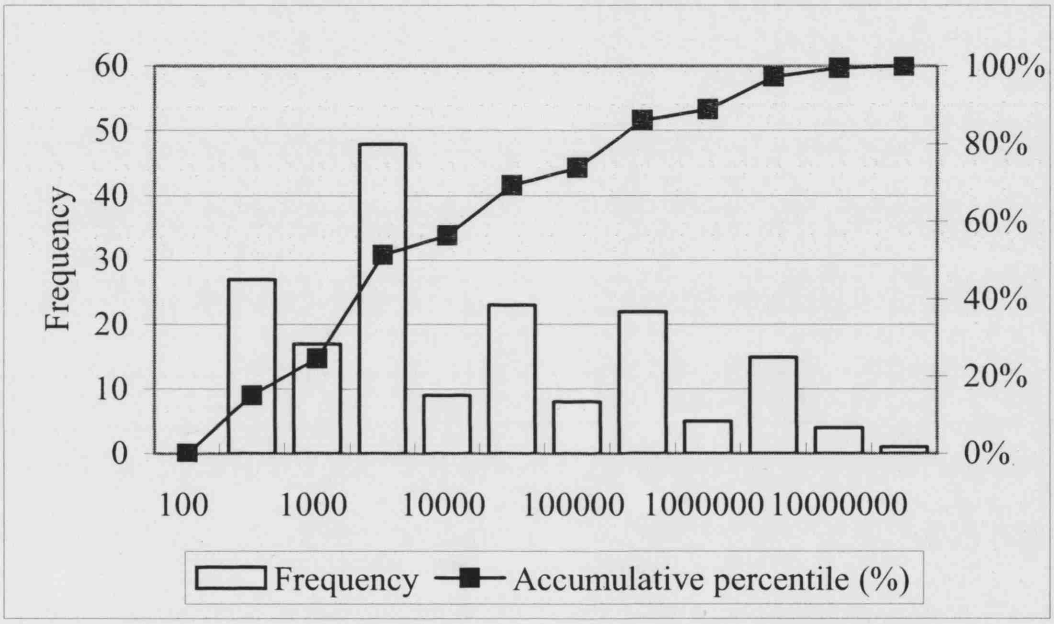

Figure 2.3.2(a) Distribution of the sizes of the global domains. The bars represent the histogram of the sizes within each range. The polygonal line graph shows the accumulative percentile (Shiode and Dodge 1999b).

The Number of Domains in Each Scale Range		
0	Frequency	Cumulative
100	0	0.00 %
500	27	15.08 %
1000	17	24.58 %
5000	48	51.40 %
10000	9	56.42 %
50000	23	69.27 %
100000	8	73.74 %
500000	22	86.03 %
1000000	5	88.83 %
5000000	15	97.21 %
10000000	4	99.44 %
50000000	1	100.00 %

Figure 2.3.2(b) Distribution of the sizes of the global domains (Shiode and Dodge 1999b).

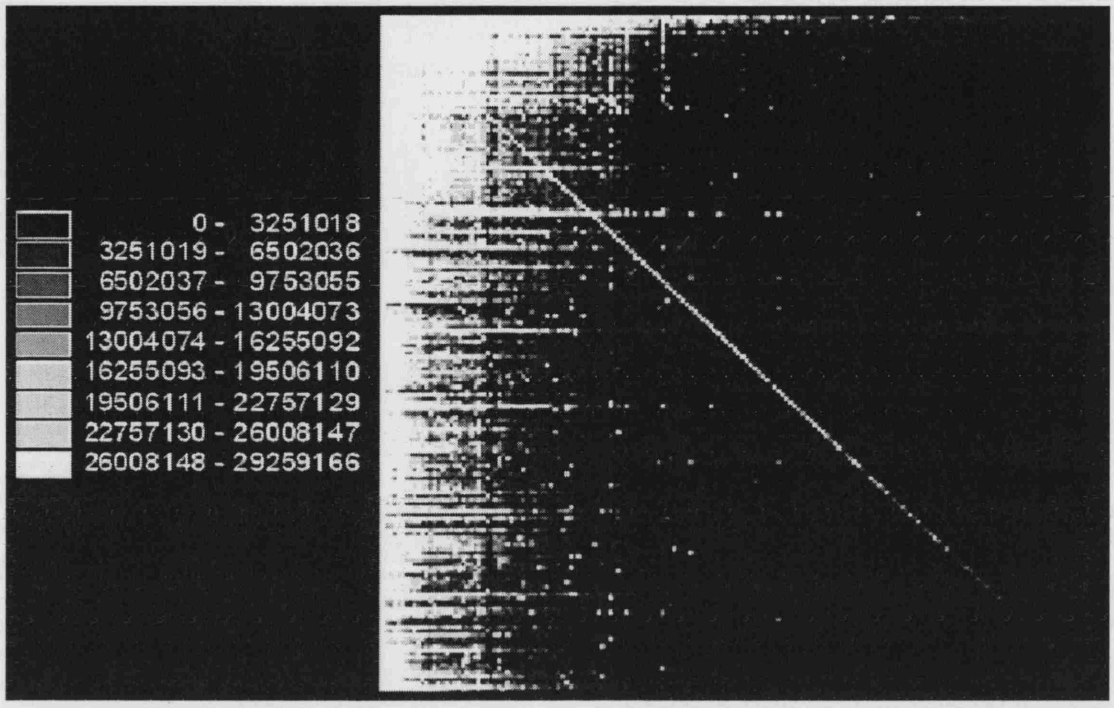

Figure 2.3.3 Hyperlink matrix of 180 global domains. Each cell represents the number of links from the outgoing site on the left column to the incoming site on the top row. The brighter the colour, more links there are between the two domains (Shiode 2001b).

Searching for the Central Location on the Web

Following the method explained in Section 2.3.3, the shortest path between each node set was explored, which helped us find the average of the minimum access distance of each domain. In order to remove the size effect in the initial data, two different indices were used as a standardisation factor and obtained the mini-sum distances in both cases. Table 2.3.5 (overleaf) shows the three different sets of top ten domains that had the shortest mini-sum distance to the others; which respectively refers to the data that are (a) non-standardised, (b) standardised by size, and (c) standardised by the number of internal links.

The table indicates that, regardless of whatever standardisation measure we take, the commercial domain (com) clearly stands out as the most well connected centre to the other domains. Thus, we fix *.com* as the centre of our Web connectivity map and measure the other domains in terms of com distance; i.e. the shortest path distance to *com*. (The complete listing of com distance of all domains is given in Table 2.3.6.)

Table 2.3.5 Three sets of top ten domains of smallest mini-sum values (Shiode&Dodge 1999b).

Non-standardised		Domain Size [(1)*]		Internal Links [(2)*]	
1 *commercial*	100	1 *commercial*	100	1 *commercial*	100
2 *education*	573	2 *Education*	1684	2 *education*	1693
3 *network*	683	3 *Network*	1756	3 *network*	2085
4 *organisation*	798	4 *organisation*	2430	4 Oman	2236
5 Japan	901	5 Germany	2432	5 Cayman Islands	2425
6 Germany	913	6 Japan	2511	6 Japan	2445
7 United Kingdom	1720	7 United Kingdom	6060	7 Netherlands Ant.	2608
8 Canada	2458	8 Guyana	7072	8 Germany	2733
9 Netherlands	4391	9 Yemen	7727	9 Belize	2792
10 Russian Federation	5945	10 Cook Islands	7885	10 Guyana	2866

* (1) Standardised by domain size; (2) Standardised by internal link size.

** The distances provided in the table are all relative.

Figure 2.3.4 shows the correlation between the "*.com*" distance standardised by the domain size and the inverse of the domain size. It appears to have a fairly strong correlation ($R^2 = 0.83$), but is more scattered overall than the non-standardised results.

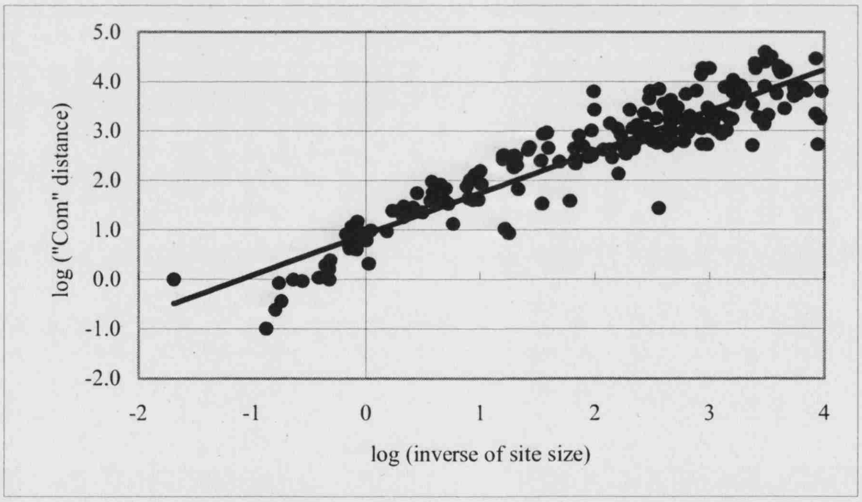

Figure 2.3.4 The correlation between "*.com*" distance and the inverse of domain size shown in the logarithmic scale ($R^2 = 0.83$) (Shiode and Dodge 1999b).

2.3.5 Visualising Global Hyperlink Connectivity

To visualise the distance of the global domains from "*.com*" we first used an astronomic metaphor of a solar-system style map. A polar coordinate grid can be particularly useful when representing the geography of an unconventional space such as that of the Web space (Slocum *et al.* 2005). The abstract space of Web geography can

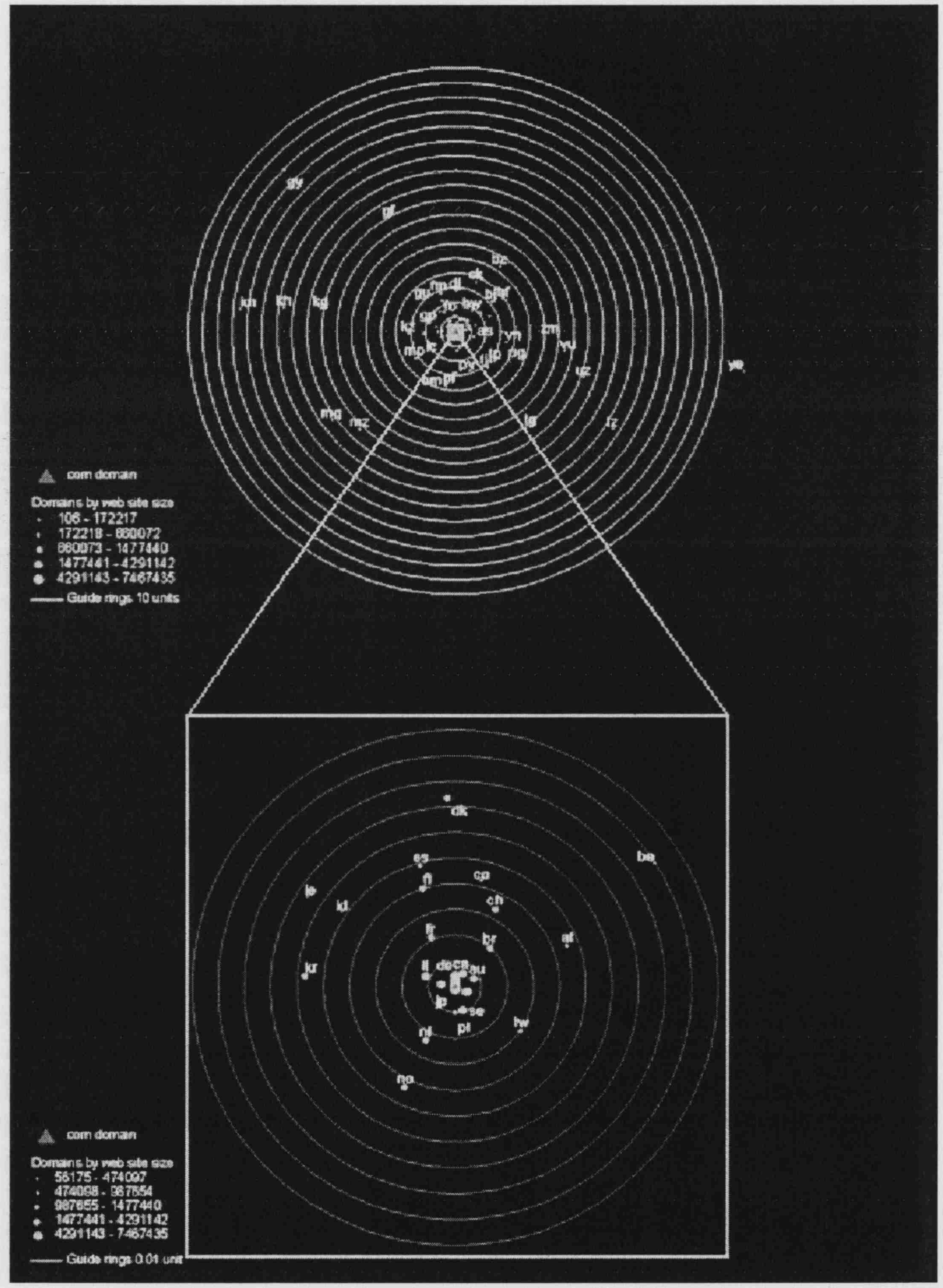

Figure 2.3.5 Web connectivity map of the global domains from 0 to 180 units (upper half of the figure). 0.001 units is equivalent of the relative distance between the centre, *com*, and its nearest neighbour, *net*. The lower half shows the central part of the Web connectivity map (from 0 to 0.1 units). A complete list of domains can be found in Table 2.3.6 (p.81) (Shiode 2001b).

be thus visualised around the "centre of web" represented by the highest connectivity, *com*. Surrounding the centre point the other domains are mapped at their minimum access distance from *com*. The domains are labelled with their two-letter country[6].

In the case of Figure 2.3.5, the orientation of the domains is arbitrary, based on a two degree interval determined alphabetically from the name of the domain, although in principle this position could be used to encode other data such as their approximate geographic location. Rings are overlaid on the map, spaced at regular distance intervals, to act as a visual guide to the scale of the system. The maps were created using ArcView GIS (ESRI, Inc.), and even though GIS technology is usually employed to analyse the real world, it also proved to be quite capable of mapping information space.

Figure 2.3.5 illustrates the minimum access distance at a different scale range, with the upper ring being the small-scale coverage of all the domains, even the most distant, least connected. The furthest away is the *ye* (Yemen) domain, which is 196 units from com, very much on the edge of the Web. Next comes *gy* (Guyana), followed by *kn* (Saint Kitts&Nevis). The centre of the map contains a dense cluster of domains with stronger connectivity to *com*.

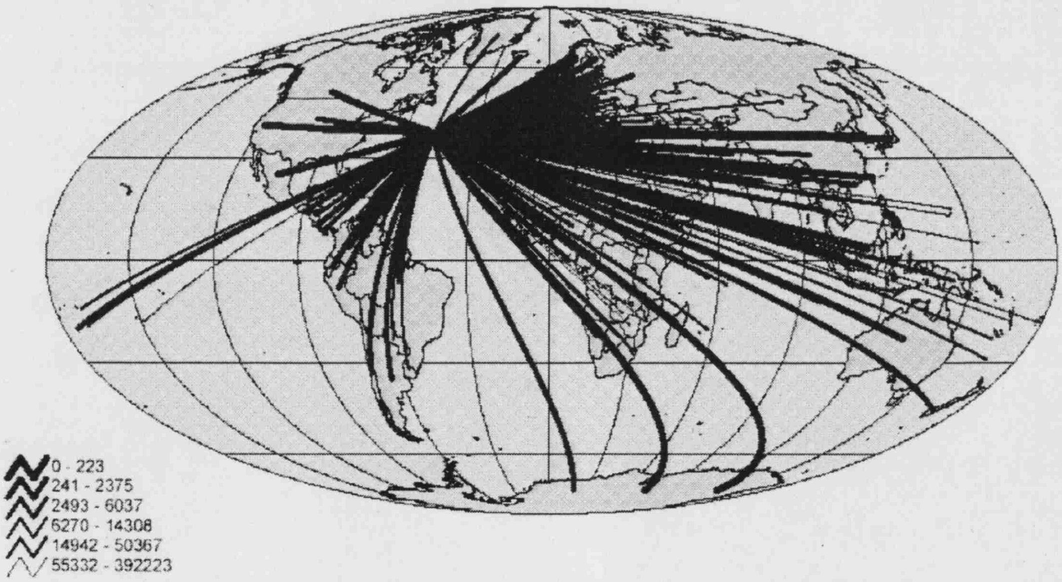

Figure 2.3.6 An atlas overlaid with the connectivity map of the global domains illustrating the virtual distance from *.com* site placed at the centre of the Atlantic Ocean (Shiode 2001b).

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[6] The country codes are based on an ISO standard, and a full listing is available at ftp://ftp.ripe.net/iso3166-countrycodes.

To see more detail of this cluster at the heart we switch to a much larger scale map (the lower part of Figure 2.3.5), which shows the twenty-seven domain's closest to *com*. On this map the size of the symbols representing the domains is drawn proportionally to that number of Web page for that domain. The peripheral domains include *be* (Belgium), *dk* (Denmark), and *ie* (Ireland).

It is apparent that, despite that the data have been standardised, the developed countries and the active industrial powers predominate the central part of the connectivity map by large, surrounding the *com* domain, with a few exceptions such as *co* (Columbia), *ad* (Andorra) and *to* (Tonga).

The connectivity of global domains can be also mapped in a more conventional way. Figure 2.3.6 is produced with a GIS tool, and it overlays the connectivity map of the global domains over an atlas to illustrate the amount of connectivity to *com*, or the virtual distance from *.com* site. It is placed at the centre of the Atlantic Ocean to indicate that no single country owns the *com* domain, but that it is rather a collective resource of the global economy. The same applies to other multi-national domains such as *org*, *int*, and *edu*, which are positioned on the Antarctic. The width of the line that connects each domain to *com* shows the amount of connectivity; i.e. the wider the edge is the more links there are between *com* and the corresponding domain.

2.3.6 Summary of Findings on the Web Analysis Study

This section analysed the connectivity of the global domains of the World Wide Web. The contribution of this section was in the proposal of the generic methodology for determining a virtual geographical distance and to carry it out with the actual data of the Web on global scale. Assuming that the assumption of the virtual geographical distance—*the number of hyperlinks between two domains determine their relative closeness*—holds, the preliminary results suggest that the Web space has its own geography that is somewhat dominated by the major economic powers in the world. Table 2.3.6 (overleaf) lists the result obtained from this study. It shows the *size* (i.e. the number of pages found under the AltaVista listing) and the *distance* (i.e. the number of hyperlinks to and from *com* sites) of each global domain.

Table 2.3.6 Domain size and the *com*-distance of the global domains in the order of their relative distance from *.com* in the information space (Shiode and Batty 2000).

Country / Domain	*	Size	Dist.	Country / Domain	*	Size	Dist.	Country / Domain	*	Size	Dist.
commercial	com	48284554	0	Philippines	ph	29752	2493	Georgia	ge	2181	14942
network	net	7467435	1	Cote D'ivoire	ci	14827	2666	Cameroon	cm	926	16501
organization	org	6176429	2	Latvia	lv	62736	2694	Bosnia Herz.	ba	632	17269
education	edu	5480765	4	Dominican Rep.	do	7136	2878	Congo	cg	109	17556
Germany	de	5760926	8	Belarus	by	11397	2905	Kuwait	kw	2926	17748
United Kingdom	uk	3554483	9	Lithuania	lt	48447	2917	Gibraltar	gi	2188	18187
Japan	jp	4291142	10	Romania	ro	50182	3148	Netherlands Antil.	an	678	18486
United States	us	2083383	10	Malta	mt	10681	3158	Nepal	np	680	18486
Canada	ca	2556128	11	Luxembourg	lu	62546	3270	Albania	al	375	18783
Australia	au	2095633	16	Macau	mo	5361	3391	Madagascar	mg	1939	19100
Sweden	se	2237539	19	Egypt	eg	10685	3409	Brunei	bn	2008	19507
Poland	pl	941280	21	Cyprus	cy	8496	4098	Bahamas	bs	1495	20073
Italy	it	2042109	24	Pakistan	pk	7420	4116	Suriname	sr	309	20786
Brazil	br	1198581	39	Venezuela	ve	38043	4162	Dominica	dm	788	21894
France	fr	1384662	42	Monaco	mc	4617	4317	Seychelles	sc	119	21978
Netherlands	nl	1400750	49	Nicaragua	ni	15129	4399	Bermuda	bm	3716	22836
Taiwan	tw	987654	61	Bulgaria	bg	25610	4497	Cayman Islands	ky	983	23396
Switzerland	ch	1217077	68	Jordan	jo	5610	4528	Virgin Islands	vi	2226	25046
Finland	fi	1477440	81	Ukraine	ua	36944	4692	Paraguay	py	4978	26389
Colombia	co	56175	85	Liechtenstein	li	12735	4814	Kenya	ke	10157	26758
Norway	no	1107890	87	Sri Lanka	lk	4906	4852	American Samoa	as	222	28205
Austria	at	660072	92	Panama	pa	2313	4917	Swaziland	sz	1040	29321
Spain	es	904287	97	SaoTomePrincipe	st	423	5071	Ghana	gh	1907	29697
Indonesia	id	61010	105	PapuaNewGuinea	pg	1053	5217	Guadeloupe	gp	419	34537
Republic of Korea	kr	1325365	115	Nigeria	ng	114	5233	Jamaica	jm	2522	35516
Ireland	ie	172217	132	Puerto Rico	pr	1175	5333	Botswana	bw	594	36936
Denmark	dk	1187042	145	Bolivia	bo	4524	5541	Saint Lucia	lc	581	41853
Belgium	be	474097	180	El Salvador	sv	2890	5650	Bahrain	bh	2185	42008
Mexico	mx	410630	216	Vatican City	va	2107	6006	Faroe Islands	fo	3376	45157
Singapore	sg	321030	223	Senegal	sn	1682	6037	Aruba	aw	184	50367
RussianFederation	ru	584276	241	Namibia	na	3188	6270	Fiji	fj	1615	55332
Andorra	ad	2793	272	Turkmenistan	tm	2791	6842	Djibouti	dj	170	56455
military	mil	386358	282	Armenia	am	3818	7381	Micronesia	fm	259	56483
China	cn	468891	294	New Caledonia	nc	2388	7636	Guam	gu	631	60325
Argentina	ar	190015	337	Azerbaijan	az	3494	7756	East Timor	tp	106	62743
Tonga	to	29149	337	Niue	nu	13887	7903	Kazakhstan	kz	10331	63036
Israel	il	200358	366	UnitedArabEmir.	ae	5969	8223	Benin	bj	493	63580
India	in	16620	379	Greenland	gl	2315	8335	Zimbabwe	zw	3310	64013
South Africa	za	270970	381	Uruguay	uy	28432	8617	Tajikistan	tj	1314	64837
New Zealand	nz	264700	392	Saudi Arabia	sa	794	8634	Northern Mariana	mp	142	64997
Slovenia	si	115226	399	Yugoslavia	yu	26419	9217	Viet Nam	vn	2771	69944
Malaysia	my	103451	402	Mongolia	mn	1543	9299	Cook Islands	ck	182	73503
Hong Kong	hk	223465	426	Qatar	qa	1670	9477	French Polynesia	pf	152	74831
Iceland	is	125834	430	San Marino	sm	2122	9761	Burkina Faso	bf	737	77709
Czech Republic	cz	358713	548	Lebanon	lb	10708	10059	Oman	om	330	80267
Portugal	pt	259240	565	Barbados	bb	713	10233	Uganda	ug	531	81964
international	int	46599	666	Antigua&Barbuda	ag	871	10265	Belize	bz	624	106951
Greece	gr	200666	668	Mauritius	mu	6356	10865	Zambia	zm	1193	138478
Turkey	tr	130324	757	Norfolk Island	nf	1629	10937	Vanuatu	vu	241	150381
Estonia	ee	220819	814	Trinidad&Tobago	tt	3501	11073	Togo	tg	217	165204
Croatia (Hrvatska)	hr	97246	830	Tunisia	tn	1184	11258	French Guiana	gf	250	179342
Hungary	hu	265079	939	Honduras	hn	4682	11385	Kyrgyzstan	kg	397	184055
Chile	cl	121839	1039	Macedonia	mk	4053	11917	Uzbekistan	uz	1149	184115
Thailand	th	111247	1284	Moldova	md	989	11977	Mozambique	mz	998	185548
Cocos Islands	cc	6241	1348	Cuba	cu	4320	13170	Martinique	mq	250	205065
Slovakia	sk	99801	1530	Niger	ne	334	13620	Cambodia	kh	401	232264
Costa Rica	cr	50829	1816	Iran	ir	1511	13726	Tanzania	tz	327	251355
Peru	pe	47752	2024	Anguilla	ai	1418	13785	Saint Kitts&Nevis	kn	118	290166
Morocco	ma	14828	2147	Guatemala	gt	7465	14022	Guyana	gy	291	318285
Ecuador	ec	20504	2375	Turks Caicos Is.	tc	1197	14308	Yemen	ye	326	392223

As this is only a preliminary case study of a single time-point based on a dataset obtained through a commercial search engine; it can be expanded from here to conduct further study on the Web structure analysis. There are a number of issues and possibilities that need to be addressed. For example, a different index can be applied for standardising the data. Also, a non-linear weighting of the domain size may be more effective in removing the data bias. Some of the data that may be available for such analysis would include the growth rate of the domains, the number of daily access to each domain, or the number of domains rather than the number of pages.

Secondly, the ratio between the incoming and outgoing links was not taken into account, and they were simply joined together to generate the relative distance. The deviation in the number of links will be discussed in Chapter 3 to examine whether the assumption on the overall equivalence of the two opposing links is valid. Relationship between the internal and external links would be another factor to think about (IBM Almaden 2000).

Finally, rapid growth of the Web suggests that frequent investigation and time-series analysis would be essential for keeping the track of the latest connectivity measures.

2.4 Geography of Cyber Cities: A Comparative Study on the Growth of Real and Virtual Cities

2.4.1 Emergence of the 3D Cyber Cities

In contrast with the previous two examples, this section focuses on the 3D virtual worlds and compares its geographical characteristics and growth patterns to those of a real city. Virtual cities were first conceptualised in science fiction literature; popularised by cyberpunk authors such as Neal Stephenson and William Gibson and their tales of vast "meta-verses" and "cyberspaces," composed of bits rather than atoms, sprawling like a megalopolis (Stephenson 1993), towering with information skyscrapers (Gibson 1984), with firewalls crafted to resemble Medieval cities (Gibson 1986). As the stories go, these cyber cities are inhabited by real people, rendered in virtual space as digital avatars of various descriptions, while maintaining a corporeal presence in the real, tangible world.

In recent years, the boundary between fact and science fiction has dissolved. Several such virtual cities have been constructed and continue to evolve online (ActiveWorlds 2005). The popularity of virtual cities is set to grow still further, catalysed by the present enthusiasm for Massively Multiplayer Online Role-Playing Games (MMORPG). Several high profile virtual cities have been opened in recent months, or are imminently forthcoming (Linden Lab 2003, Maxis 2002, 2003, There 2003).

Virtual cities have obvious appeal in the context of gaming and entertainment. They have other, academic, uses, as well. Researchers in urban studies have long used simulation as a planning support tool (Shiode 2001a, Torrens 2002). The rationale is that simulations can function as virtual laboratories for testing hypotheses, ideas, plans, and policies in artificial urban systems, in ways that are not feasible or may be impractical in the real world. Simulations of this nature generally portray urban systems in very abstract terms—although that is beginning to change (Torrens 2003). In particular, the representation of urban spaces, structures, patterns, and morphologies in traditional urban simulation contexts is often cursory.

Cyber cities that are developed in the MMORPG tradition offer fantastic potential as planning support tools, because they are populated by *real* people, replacing the synthetic, "mean individuals" commonly found in urban simulation models. The emphasis in classic urban simulation is on *mimicking* urban processes, generally using a variety of algorithms, equations, or transition rules. In virtual cities, by contrast, urban spaces are configured and generated by real people. Citizens of virtual cities act as designers, architects, planners, developers, policy-makers, and inhabitants in their virtual urban environment (Shiode 2001a). Virtual cities thus open up a new world of research potential. Yet, very little work has been done in this area. Research into *social* interactions, discourse, and behaviour in online worlds abounds, and is carried out in fields external to urban studies. Nevertheless, little attention has been paid to virtual cities as *urban spaces*, despite the obvious advantages of using virtual cities as laboratories for research in urban studies (Shiode 2000, Shiode and Torrens 2003a).

In this section, we examine the production of cities—the manner in which urban space is developed and populated—in the longest-running virtual city, AlphaWorld. A particular focus is on determining the extent to which *virtual* cities in AlphaWorld resemble their *real* world counterparts; in this case, Austin, Texas. Austin is identified as a city that share many common features with its virtual counterpart, including the flat topography, comparable size, and rapid growth over recent years. Rigorous empirical methodologies from other existing disciplines—such as spatial analysis, complexity studies and Geographic Information Science—have been applied for comparing and contrasting the virtual and tangible urban environments. It also employs the use of evaluation technique adopted for analysing patterns of suburban sprawl in North American cities (Torrens and Alberti 2000) and regularities in the rank-size scaling of metropolitan areas (Batty and Shiode 2003).

Section 2.4.2 reports the recent urban trends in the two case cities, AlphaWorld and Austin, Texas. This is followed by the analysis and its results which are presented in section 2.4.3, focusing on comparative complexity and symmetry respectively. Section 2.4.4 concludes the entire section by discussing the findings, their implications in the context of urban studies, and outlying potential avenues for further exploration.

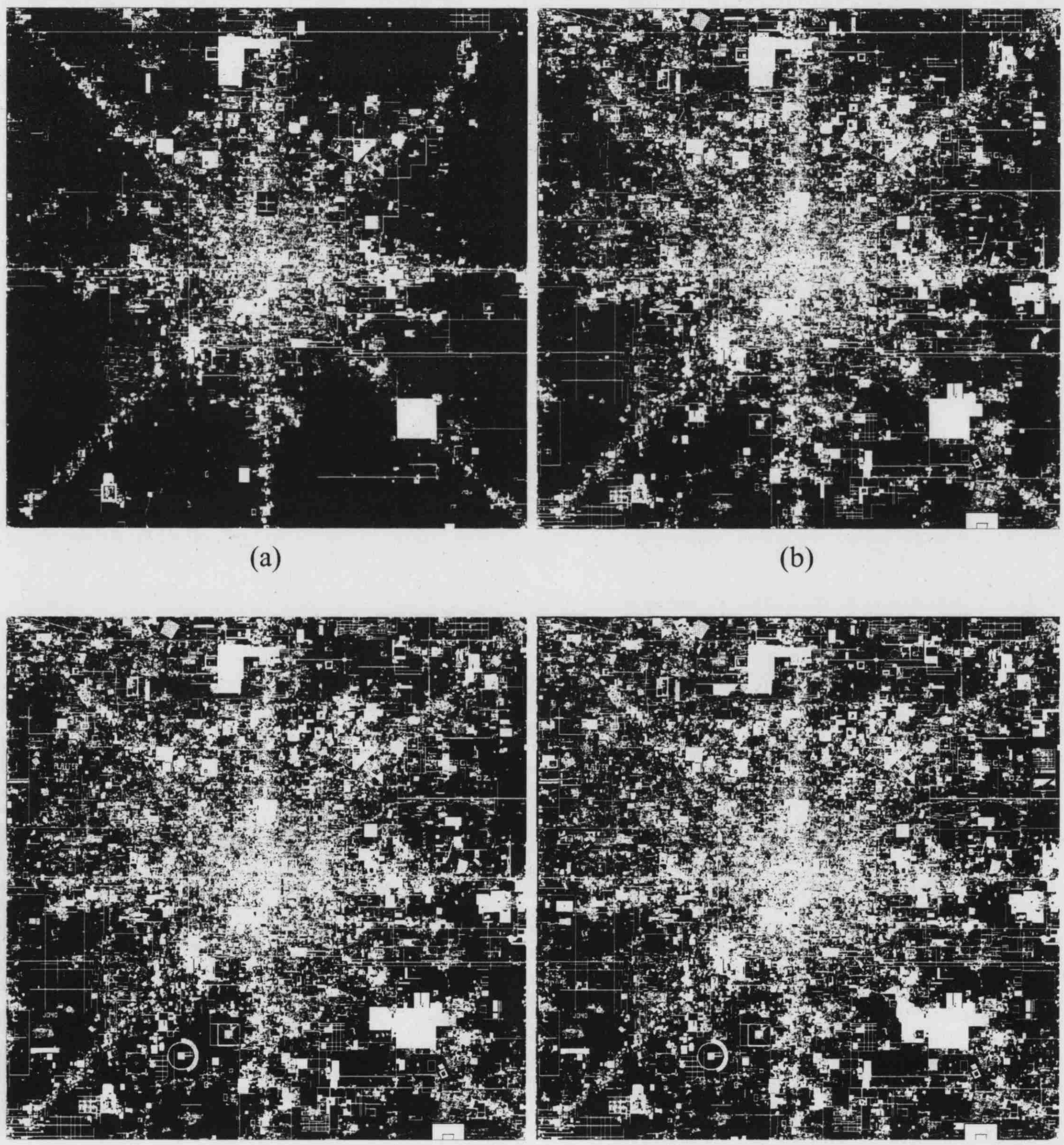
2.4.2 A Tale of Two Cities—AlphaWorld and Austin, Texas

<u>AlphaWorld: an immersive 3D cyber city</u>

AlphaWorld is an immersive, multi-user, 3D cyber city. The world is generated electronically and rendered within the virtual environment of the Internet. Users interface and interact with and within the world by logging-in from a networked computer (Shiode 1997b). The world has a surface area equivalent to 429,025 sq. km—it is comparable in size to the state of California. The world is rendered, in two-dimensional space, as a cube; and the spatial extent spreads from a central point, *Ground Zero* (0N 0W) to all four corners—from (32,750S 32,750E) to (32,750N 32,750W). Within this plane, users have constructed 3D cities. The world has been active since 1995. It is still thinly populated, but has a rapid growth rate. As of August 8, 2002, there are 127.6 million objects in AlphaWorld, but only 65.1 million unit cells within its boundary (1.52% of the total number of cells) contain man-made objects (Roelofs and van der Meulen 2002).

AlphaWorld is a pseudo-3D environment in the sense that users can "walk about" in the streets and "talk" to other people. The world is incredibly flexible; users are free to construct their own buildings and interact with other users (see, *mapper.activeworlds.com/aw/about-full.html* for more information). Nevertheless, it also retains certain unique *spatial* features where users can enter arbitrary coordinates and instantly "teleport" to a location.

Figure 2.4.1 illustrates changes in the land cover for AlphaWorld over a five year period. The maps illustrated in Figure 2.4.1 cover the area between (1000N 1000W) and (1000S 1000E) of AlphaWorld, an area equivalent to 400 sq. km (roughly 0.3% of the total area of AlphaWorld). Ground Zero is at the centre of the picture.



(a) (b)

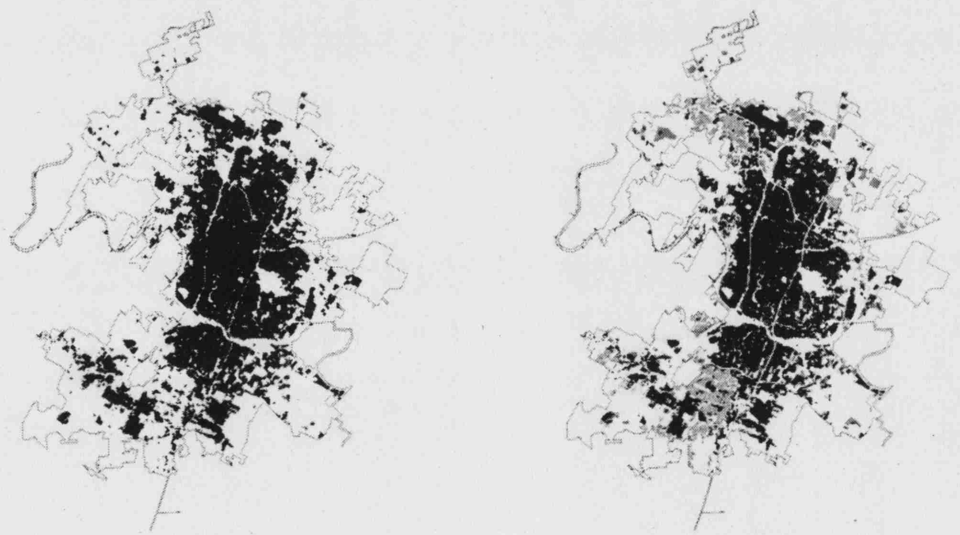
(c) (d)

Figure 2.4.1 Building footprints in the central 400km^2 area of AlphaWorld (a) December 1996, (b) February 1998, (c) August 1999, (d) August 2001 (source: Activeworlds 2005).

Considering the maps in a purely visual sense, a number of striking phenomena are apparent. First, the area has obviously undergone dynamic development. This has been both rapid and complex in its manifestation. In particular, the maps illustrate incremental development in a monotonic fashion, characteristic of a classic concentric city. Second, development is focused around a central core area, with a high degree of concentration along two central axes and the diagonals. This "starfish" morphology is due to the unique coordinate teleporting system in AlphaWorld—people tend to focus their building activity along the North-South axis and the "equator," and they also tend to build along coordinates with matching numbers (e.g. 123S 123W). These regularities are not at all uncommon in real cities.

Austin, Texas: a fast growing real city

The city of Austin is only the 38th largest city in the United States, occupying 625 sq. km of land in Southern Texas. Nevertheless, it ranks as the fifth-fastest growing city in the United States (Table 2.4.1); its population expanded by almost 50% in the last decade. Not surprisingly, the urbanised area has expanded at an unprecedented rate (Figure 2.4.2).



(a) (b)

Figure 2.4.2 Urban growth in Austin, Texas in (a) 1990 and (b) 1995 (growth shown in grey) (Shiode and Torrens 2003a).

Table 2.4.1. The top ten fastest-growing cities in the United States. (Source: U.S. Census Bureau, Census 2000 Redistricting Data (P.L. 94-171) Summary File and 1990 Census.)

		Census Population		*Change 1990-2000*	
Rank	*Metropolitan Area Name*	*April 1990*	*April 2000*	*Number*	*%*
1	Las Vegas, NV-AZ	852,737	1,563,282	710,545	83.3%
2	Naples, FL	152,099	251,377	99,278	65.3%
3	Yuma, AZ	106,895	160,026	53,131	49.7%
4	McAllen-Edinburgh-Mission, TX	383,545	569,463	185,918	48.5%
5	**Austin—San Marcos, TX**	**846,227**	**1,249,763**	**403,536**	**47.7%**
6	Fayetteville-Springdale-Rogers, AR	210,908	311,121	100,213	47.5%
7	Boise City, ID	295,851	432,345	136,494	46.1%
8	Phoenix-Mesa, AZ	2,238,480	3,251,876	1,013,396	45.3%
9	Laredo, TX	133,239	193,117	59,878	44.9%
10	Provo-Orem, UT	263,590	368,536	104,946	39.8%

Austin has several similarities with AlphaWorld that make it a good candidate for comparison. Although it was originally founded in the Eighteenth Century, Austin's population did not grow above one thousand people until the late-Nineteenth Century. However, it has undergone rapid growth and urbanisation in very recent years, as is the case in AlphaWorld. The land area that Austin occupies (625 sq. km) is comparable with that of the sections of AlphaWorld (400 sq. km) for which we have map data. (Incidentally, Texas covers 678,051 sq. km of the United States—roughly 1085 times larger than Austin, which again is comparable to the entire area of AlphaWorld, 429,025 sq. km—1073 times the central area.) Austin also shares a flat topographical feature with AlphaWorld. Austin is also a poster-child for growing concern about sprawl, urban sustainability, and smart growth; these are some of the issues that we are interested in exploring in virtual cities. In the following section, we will compare the two cities by extracting and examining their spatial patterns.

2.4.3 Growth Analysis of the Real and Virtual Cities

Both AlphaWorld and Austin show a significant increase in their land-use development over a short period of five years. The rapid growth and the increasingly complex urban structure are also evident in Figures 2.4.1 and 2.4.2. Between 1996 and 2001, land-use in AlphaWorld has soared by 130%, and now has a high land coverage rate of 36% (Table 2.4.2). Austin has also seen a significant increase; 27% growth in land-use development between 1990 and 1995 (Table 2.4.3).

Table 2.4.2 Land-use development in the central AlphaWorld (Shiode and Torrens 2003a).

Date	*Built units (% of the area: 1048576)*	*Standard deviation*	*Increase from the previous survey*
December 1996	164138 (*15.38%*)	92.66	
February 1998	307502 (*29.33%*)	116.09	187.34%
August 1999	347794 (*33.17%*)	120.06	113.10%
August 2001	376700 (*35.93%*)	122.34	108.27%

Table 2.4.3 Land-use development in Austin, Texas (Shiode and Torrens 2003a).

Year	*Built area (% of the area: 1048576)*	*Standard deviation*	*Increase from the previous survey*
1990	129974 (*12.40%*)	84.03	
1995	164513 (*15.70%*)	92.74	126.57%

In terms of the increase in complexity and land coverage in the two cities, we can compare them by examining changes in their fractal dimensions (Tables 2.4.4, 2.4.5). Fractal dimension measures the proportion of a space that is filled and the manner in which it is filled; in general, the higher the value, the denser and more complex the structure. Correlation coefficients are an indication of statistical self-similarity; i.e. whether a land cover pattern retains an overall consistency over a wider area, as well as across different scales.

The values in Tables 2.4.4 and 2.4.5 suggest that both cities have undergone consistent growth and have formed an increasingly complex, yet regular pattern within their respective systems. Note that well-established cities like London had a fractal dimension of 1.737 already as early as in 1900 and have only observed a moderate increase since then—its fractal dimension in 1962 was still D = 1.774 after 88 years) (Abercrombie 1945, Doxiadis 1968). Nonetheless, we expect, the growth rates of AlphaWorld and Austin to drop dramatically, as they are quickly approaching the critical limit of space filling: a fractal dimension of D = 2, which would mean a complete filling of the entire plane they occupy. It is popularly known that most spatial structures, including urban systems, have an upper threshold for their growth, which is determined by the space occupied by streets, public parks and other open area (Batty and Longley 1994).

Table 2.4.4 Change in fractal dimensions of AlphaWorld (Shiode and Torrens 2003a).

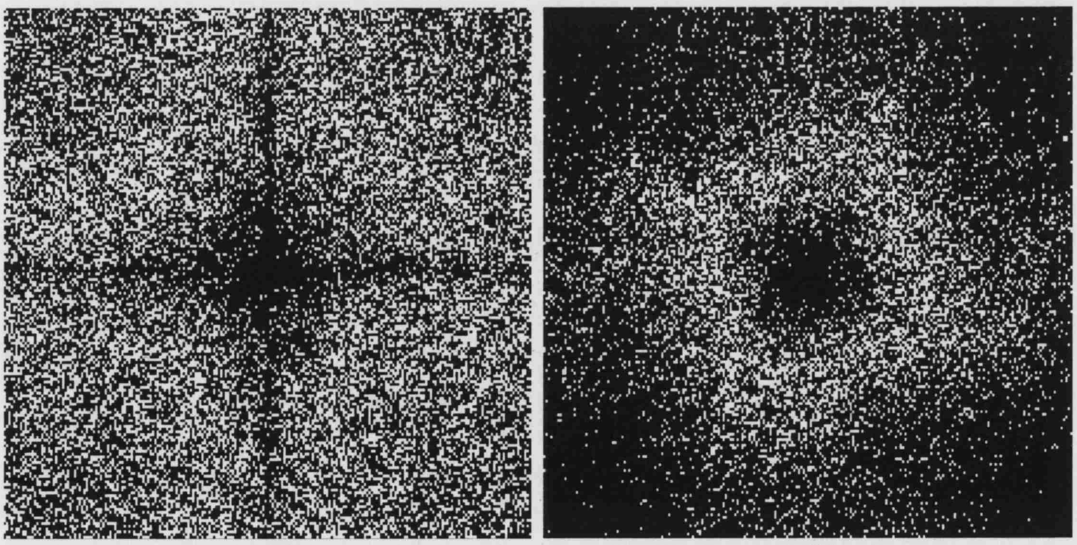
Date	*Fractal dimension*	*Correlation coefficient*	*Mean square error*
December 1996	1.729353	0.998244	0.067830
February 1998	1.842562	0.998675	0.062746
August 1999	1.865861	0.998763	0.061389
August 2001	1.880098	0.998855	0.059502

Table 2.4.5 Change in fractal dimensions of Austin, Texas (Shiode and Torrens 2003a).

Year	*Fractal dimension*	*Correlation coefficient*	*Mean square error*
1990	1.664272	0.999663	0.028552
1995	1.701267	0.999608	0.031475

2.4.4 Symmetry Analysis of the Real and Virtual Cities

AlphaWorld and Austin also share a common spatial feature in that both of them are highly symmetrical; and this property is evident throughout their growth history. However, their similarity ends there. The actual shape of land cover in the two cases shows stark contrast, as can be seen in their angular frequency spectrums (Figure 2.4.3). AlphaWorld has a highly diffused spatial structure, with strong regularity around the central axes; whereas Austin has a solid central urban, surrounded by a less densely inhabited area that sprawls toward every direction (Shiode and Torrens 2003a, 2003b).



(a) (b)

Figure 2.4.3 Visualisation of the angular frequency spectrum ($-\pi \sim \pi$) in (a) the central 400km^2 area of AlphaWorld as of 2001 and (b) the central area of Austin, Texas as of 1995 (Shiode and Torrens 2003a).

Also, if we take the grey level histogram, AlphaWorld has a high average value 91.61 out of a possible 255 (equivalent to 35.93% in area coverage) and variance as high as 14968.05, but its skewness (which indicates the amount of deviation from symmetric histogram distribution):

$$S = \frac{\sum_{i=0}^{n-1}(i-\mu)^3 P(i)}{\rho^3} \tag{2.4.1}$$

and kurtosis (which indicates the degree of concentration of its histogram distribution around the average value):

$$K = \frac{\sum_{i=0}^{n-1}(i-\mu)^4 P(i)}{\rho^4} \tag{2.4.2}$$

are low—0.59 and 1.34, respectively.

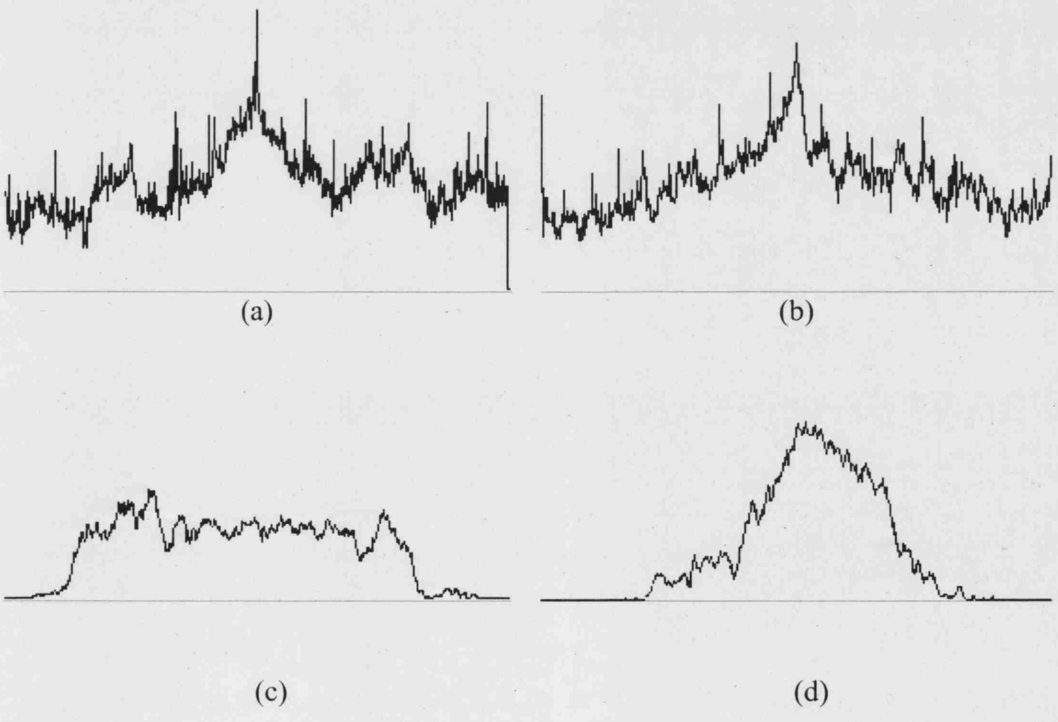


Figure 2.4.4 Projections of density distributions in central AlphaWorld (as of 2001) and Austin (as of 1995): (a) horizontal projection in AlphaWorld, (b) horizontal projection in AlphaWorld, (c) horizontal projection in Austin, and (d) vertical projection in Austin (Shiode and Torrens 2003a).

By contrast, the grey level histogram for Austin in 1990 has a lower average value (E = 31.61 out of a possible 255, which is equivalent to 12.40% in area coverage) and lower variance (V = 7060.97), but much higher skewness (S = 2.28) and kurtosis (K = 6.21).

Also, the vertical and horizontal projections of each maps (Figure 2.4.4) suggest that, while they both maintain an overall symmetry in their structure, AlphaWorld is much more dispersed over its landscape, mainly because of the concentration around the outreaching axes and diagonal lines (Figures 2.4.4(a), 2.4.4(b)); whereas in the case of Austin, there is a significant concentration toward the middle section of the map: its downtown (Figures 2.4.4(c), 2.4.4(d)).

The same patterns are evident in the statistical geometrical texture description.

The energy level ($\sum_{i=0}^{n-1}\sum_{j=0}^{n-1}(i,j)^2$) across the density distribution is consistent—0.76 ($\theta = 0, \frac{\pi}{4}, \frac{\pi}{2}, \frac{3\pi}{4}$) for Austin (as of 1990); AlphaWorld has a much lower range at 0.40 ($\theta = 0, \frac{\pi}{2}$) and 0.36 in diagonal directions: $\theta = \frac{\pi}{4}, \frac{3\pi}{4}$, which again explains the overall diffusion. In addition, the inertia levels (i.e. the resistance to changes in density: $\sum_{i=0}^{n-1}\sum_{j=0}^{n-1}(i-j)^2 P(i,j)$) for AlphaWorld range from 151.47 ($\theta = 0$) to 221.82 ($\theta = \frac{3\pi}{4}$), which are a magnitude larger than those of Austin: 16.89 ($\theta = 0$) to 21.70 ($\theta = \frac{3\pi}{4}$). All these statistics point towards the fact that whilst both AlphaWorld and Austin have highly symmetrical land cover patterns, Austin has a strong concentric structure, as compared to the radial pattern of AlphaWorld.

2.4.5 Summary of Findings on the 3D Cyber City Study

This section presented results from a comparative study on the urbanisation trends of two fast-growing cities, one in real and the other in virtual space: Austin, Texas, and AlphaWorld. Preliminary exploration shows some striking similarities between the two cities. Both are sprawling, at unprecedented rates and in similar styles. The rate of growth is also comparable, as is the area of land cover. Both are developing at lower-than-average densities on the periphery of the urbanised mass, both exhibit symmetrical structures, and both have fractal signatures that indicate a high degree of scattering and fragmentation in land-use.

Nevertheless, there are some notable differences. While both cities are sprawling in a similar fashion, the *nature* of that sprawl varies considerably between the two cases. Closer analysis reveals significant variation in the pattern of urbanisation. AlphaWorld has string axial orientation, radiating from its central area in horizontal, vertical, and diagonal vertices. Austin, on the other hand, has strong concentric clustering in its spatial distribution. Spectral analysis demonstrates the statistical significance of the variation.

Austin appears to follow the classic stereotype for suburban sprawl in North American cities: a loose and fragmented suburban ring orbiting a central core (Figure 2.4.3a). Alternatively, AlphaWorld appears to exhibit two urbanisation trends simultaneously: classic sprawl, but organised in a polycentric fashion (Figure 2.4.3b). The result is a thin layer of fragmented urban clusters.

Of course, we are discussing a *virtual* city, but the implications for urban planning and policy in the real world may be significant. To a certain degree, the construction of urban space in AlphaWorld is indicative of the types of urban forms that people would *like* to build in the real world. The pattern of urbanisation in AlphaWorld can be regarded as a hybridisation of two very popular trends in Western development and settlement patterns. The *behaviour* of people in this cyber-city may seem like science fiction: people building without concerns for zoning regimes or planning codes, or care for distance and the capacity to move freely across the landscape. However, to some extent, the situation in AlphaWorld mirrors current trends in the real world: development in the southwest of the United States, for example, appears in many cases to be exercised with little consideration for planning. The ubiquity of highways and the public's stated preference for vehicular travel is also creating environments in which space is beginning to matter less and less. To a certain degree, AlphaWorld is suggestive of future trends in urbanisation.

CHAPTER III

SCALING PATTERNS OF INFORMATION SPACE

Modelling the Growth Dynamics of Cyberspace Using Its Scaling Tendency

3. SCALING TENDENCY OF INFORMATION SPACE

In the previous chapter, we categorised the range of information spaces with respect to their spatial attributes. A series of case studies on the subset of each type of information spaces was carried out and was discussed in order to understand the nature of such spaces. This chapter further investigates their spatial characteristics by looking at the scaling tendency found within each of the subsets that were previously discussed. It will also compare their distribution patterns to that in the real world to contexturise their geographical distribution. Based on these insights, we will build a conceptual model of information space inspired by a scaling, growth model in astro-physics.

3.1 Scaling Distributions in Real and Virtual Worlds

3.1.1 Revisiting the Interpretation of the Web Space

Using the same dataset from Section 2.3, this section compares the statistical patterns of size and connectivity of the global domains (as in "*.com*" and "*.uk*") to the geographical distribution of the global population. We have learned in Section 2.3 that, as the development of Web sites represents the cutting edge of the new global economy, their sizes and contents are likely to reflect the distribution of population and the urban geography of the real world (Shiode and Dodge 1999b). There is widespread evidence that population and other socio-economic activities at different scales are distributed according to the rank-size rule and that such scaling distributions are associated with systems that have matured or grown to a steady state where their growth rates do not depend upon scale (Shiode and Batty 2000, Batty and Shiode 2003). In this section, we advance the hypothesis that the growth of Web pages in different domains is not yet stable. This is supported by our analysis that shows that the most mature domains with the most pages follow near rank-size relations but those countries, which are much less advanced in their development and use of internet technologies show size relations which, although scaling, do not conform to rank-size. The underlying assumption is that as the Web develops, all domains will ultimately follow the same power laws as these technologies mature and adoption becomes more uniform. The structure in the cross-sectional data collected is consistent with a system which is rapidly changing and has not yet reached its steady state.

In general, as Web sites clearly form an integral part of social and economic development, their sizes and contents are likely to reflect the distribution of population and the urban geography of the real world (Gorman 1998, Mitchell 2002). It has been predicted that, despite its apparent arbitrariness, the sizes of Web sites and hyperlinks between them follow known distributions of growth phenomena such as those observed for cities and regions (Albert *et al.* 1999, Huberman and Adamic 1999, Huffaker *et al.* 2002).

We begin by reviewing the concept of rank-size rule and the recent investigations in their study (Section 3.1.2), and we then extend this to Web sites which are distributed geographically in real space (Section 3.1.3). Through a comparative study of the sizes of global domains and national populations, we argue that the sizes and frequencies of Web sites follow those well-known scaling distributions first catalogued for a variety of different social phenomena by Zipf (1949), and subsequently widely applied to city size, income, word frequency, and firm size distributions (Section 3.1.4).

3.1.2 Power Laws, Scaling and Rank-Size: Zipf's Law Revisited

Before the scaling tendency of the distributions patterns in information spaces is discussed, this section briefly reviews the concept of rank-size rule and the scaling tendency. Distributions in nature and economy which are composed of a large number of common events and a small number of rarer events often manifest a form of regularity in which the relationship of any event to any other in the distribution scales in a simple way. In essence, such distributions appear to arise through growth processes which do not favour the common or rare events and which involve random additions to the set of events or objects. Typically, the size of an event $P(x)$ scales with some property of the event x in the form $P(x) = Kx^{\alpha}$ where K is a constant and α some parameter of the distribution. Such distributions are scaling in that the size of the event is proportional to the size of the property; that is, if the property grows by λ, then the size scales as $P(\lambda x) = K(\lambda x)^{\alpha} = \lambda^{\alpha} K x^{\alpha} = \lambda^{\alpha} P(x)$. From this it is clear that $P(\lambda x) / P(x) = \lambda^{\alpha}$ which has a particularly simple form when $\alpha = 1$.

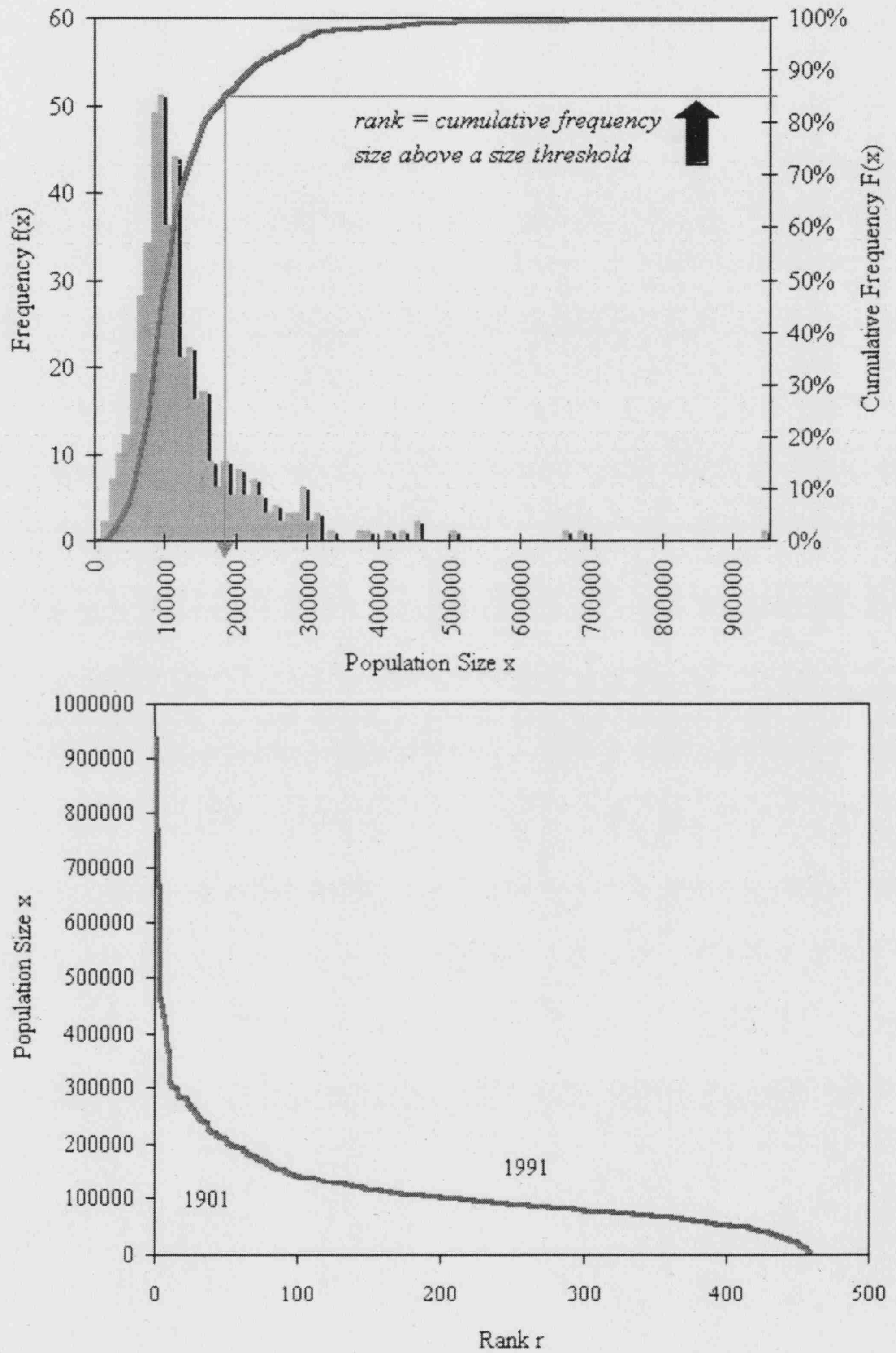


Figure 3.1.1 Frequency, Cumulative Frequency and Rank-Size based on the British Population in 1991 (Batty and Shiode 2002).

These relationships can be formulated either in simple frequency form or in cumulative frequency form, usually as a rank-size relationship, which is preferred in this case, when the focus is on the rarer or larger events that dominate the distribution (see Figure 3.1.1 for an example).

The best known of these scaling laws is the rank-size rule which was first popularised by Zipf (1949) for cities, word frequencies, and income distributions. Zipf's Law, as it is called, has the general form $P(r) = Kr^{-q}$ where $P(r)$ is the size of the event, in the case of cities - the population, r is its rank in descending order of size where $P(r) > P(r+1)$; q is some parameter of the distribution and K is a scaling constant. Sometimes the relation is presented as $P(r)r^{q} = K$ for any r which implies some form of steady state consistent with the growth process. The relevance of such simple scaling to city-size distributions has been known for over 100 years. Auerbach (quoted in Carroll 1982) proposed that the exponent q was 1 in 1913, while Lotka (again in Carroll 1982) suggested that $q = 0.93$ in 1925. Zipf (1949) and many others since then (see Krugman 1996) have confirmed this 'iron law' of city sizes. The usual way of fitting such distributions to data (which we follow here) is to perform a linear regression of $\log P(r)$ on $\log r$ where the parameters $\log K$ and q are the slope and intercept of the curve $\log P(r) = \log K - q \log r$, respectively.

There is considerable debate as to whether the systems and their size distributions modelled with power laws of this form are best represented by such log-linear relations. In fact, the Yule and log-normal distributions generated by various growth models and even stretched exponential, parabolic fractal and related forms might be preferable for distributions with fat, heavy or long tails (Laherrere and Sornette 1998). Here, however, we will develop the rank-size model largely because it represents a first attack on the problem of measuring the size of the Web, and there are good stochastic models that are consistent with the kinds of distributions that we observe. In particular, Simon (1957) has developed a growth model which is based on three assumptions that appear to fit many natural and social systems. First, new events or objects are created at a regular but random rate and of the smallest size. Second, the growth rate of all existing events is essentially random, and third, the rate is independent of the size of objects, but with average actual growth proportional to size. As the number of events grows, their distribution converges to the steady state $P(r) = Kr^{-q}$ with $q = 1/(1-\pi)$ where

$\pi < 1$ is the average growth rate of events which in the steady state converges to zero. This is a very useful interpretation; when the growth rate is near to 1, it means high value of q and hence, indicates that the system is in its immature early stages, akin to that, for example, associated with the Web. As we will show below, our null hypothesis is that the system is already in the steady state with $q \approx 1$ but that deviations from this (which we will see in the rank-size plots), will indicate how far different domains (countries) in the system are from the steady state.

Several other models also appear appropriate as the explanation for the formation of the rank-size. Simon's (1957) model is indeed equivalent to those which generate the Yule and log-normal distributions where the short tail of the distribution does not accord to the rank-size relation. In fact, most applications of scaling laws to these kinds of distribution 'conveniently forget' the short tail, fitting the model to the long tail, on the assumption that the size of events has to pass a certain threshold before the maturity of rank-size takes effect. The Simon model can be seen as compatible with the explanation of the short tail, although this point will be only briefly explored in this section.

So far, the strict rank-size rule has not been applied to the distribution of Web pages and their hyperlinks for different country domains. However, Albert *et al.* (1999) use pure scaling to measure the frequency distributions of the numbers of in-degrees and out-degrees of links from Web sites, with implied values of $q \approx 1.45$ and $q = 1.1$ respectively for the associated rank-size relations. Faloutsos *et al.* (1999) have examined out-degrees from internet domains at three points in time in 1997-1998, and show that the equivalent q exponent varies from 0.81 to 0.82 to 0.74 for the rank-size rule and from 1.15 to 1.16 to 1.20 for the same data fitted in its simple frequency form. However, because these contributions stress connectivity, both works are almost entirely associated with hyperlinks found between a subset of the Web which is, at one level, comparable to the air route network in the real world, as opposed to the Web sites being the equivalent of city sizes.

In fact the fundamental concept of the power law can be considered to perform at its best when ranking a non-directional, agglomerative or accumulative set of events (or objects) that are spatially dispersed over a certain area. This complies with the developments of scaling laws in physics as well as in biology. Moreover, in order to comprehend the Web in a geographical context, it is essential to compare various distribution patterns associated with the size of the Web with those of the real world. In this light, we can measure the size of domains at the global level as well as hyperlinks observed within and between them (Section 3.1.4). In order to interpret the data in the context of real world geography, they can be compared with the distribution patterns of national population and GDP. This would not only contextualise Web size with a real geography, but also help further to ground the earlier results obtained by the Albert (1999) and Faloutsos (1999) groups.

3.1.3 Data Sources and Information on the Web Analysis Study

In order to carry out the comparative study of the Web and the real-world geography with a focus on their scaling tendency, several data for population, GDP, Web site size and hyperlinks have been collected—the full listing of which is given in Table 3.1.3. The web size and hyperlink data are the same dataset from ***AltaVista*** that were used in Section 2.3 for the case study on Web spaces. Real GDP in billions of $US for 1998 (at 1990 values) and total population for 1994 were taken from IMF World Outlook (IMF 1999) and the GIS package ***Map/Info Professional*** respectively. Although the initial data set contained 180 global domains, some of the data were immediately excluded to reduce them to 151 data points for the following reasons:

(1) Consistent data could not be obtained for some countries and regions that have recently undergone radical transitions such as major political change or war (e.g. Hong Kong, or Macedonia). The same applies to some regions with autonomous governments which are nonetheless part of other countries.

(2) The breakdown for the non-regional domains such as "*com*," "*int*," "*net*," and "*org*" was difficult to estimate, and the 'correct' proportion could not be assigned to each participating country. There is some discussion that the US industries have up to 60% share of "com," (Gray 1995) but the actual ratio remains uncertain, and breakdowns for the other three domains are unpredictable.

(3) Considering the impact it has upon the entire rank, we included the US in our preliminary analysis, despite the above remark. We defined the US domain as a combination of the following: *United States* (*us*), American Samoa (*as*), Guam (*gu*),

Puerto Rico (*pr*) and US Virgin Islands (*vi*); also *education* (*edu*), *government* (*gov*), *military* (*mil*) and 50% of *commercial* (*com*). As US firms may actually make up a significantly different percentage from 50% of "*com*" and other super-national domains, this introduces considerable uncertainty into the analysis. This ambiguity, however, would not have significant effects on rank-size analysis, if we were to focus on the rank size distribution below the second and lower rank domains. Abnormal values of highest ranked events are a common phenomenon. Primacy, in city size distribution, for example, has to be dealt with as reflected in large political and historical centres such as Paris, London and Berlin (Berry and Horton 1970), but in general, this does not lead to inconsistencies in rank-size *per se*.

(4) A tremendous number of hits were observed for countries with a peculiar domain suffix such as Columbia (*.co*) or Tonga (*.to*). This is likely to be caused by the purchase of these popular sounding domain names by the firms and individuals residing outside the country in question and this will certainly distort comparisons with the distribution of population as well as GDP. As yet we do not have a method for measuring the impacts of external contributors, and thus have to accept any such data at its face value. On the other hand, such peculiar agglomerations, especially those that differ from the GDP distribution pattern, may reflect a new geography of information space.

The domain size ranged from the super-scales of "com (*commercial*)": 48,284,554 pages, and "net (*network*)": 7,467,435; down to small country domains such as "*cg* (Congo)": 109, and "*tp* (East Timor)": 106.

The number of links between the 180 global domains was also investigated. As stated in Section 2.3, we observed, within the 16,111 possible combinations, a total of 76,735,152 links of which 16.1% (12,318,346 links) were found between *com* and *net*.

Correlations between the Web size and the total number of links assigned to domains regardless of direction (that is, both incoming and outgoing links), are shown in Figure 3.1.2, together with those based on population and GDP (Figure 3.1.3). It is not surprising to find an r^2 for Web size and hyperlinks of 97%, but this simply confirms consistency in the average number of links per page. The overall average was 3.92, much lower than the 7 obtained by Albert *et al.* (1999). This may be explained in part by the differences in the methods of data collection. Albert's group counted the number of pages at some specific sites such as those of their own research institutes as well as the White House whereas this data, while globally obtained, depends on a commercial search engine (Shiode and Batty 2000, Batty and Shiode 2003).

3.1.4 Analysis and Interpretations on the Scaling Tendency of Web Space

Figures 3.1.4(a)~(c) (p.103) respectively show the relationship between the size and the rank size of global Web sites, demographics, and economic data in the descending order. Each distribution is measured by the number of Web sites for each primary domain, number of incoming links into each domain (in-degrees), number of outgoing links (out-degrees), total links associated with each domain (in-degrees and out-degrees and inter-domain links), real GDP in billions of dollars US, and national population. Figures 3.1.4(a)~(c) present a graphical analysis of this data, plotting the distributions on logarithmic scales, visually associating various data, and computing idealised and actual rank-size relations; i.e. fitting the trend line.

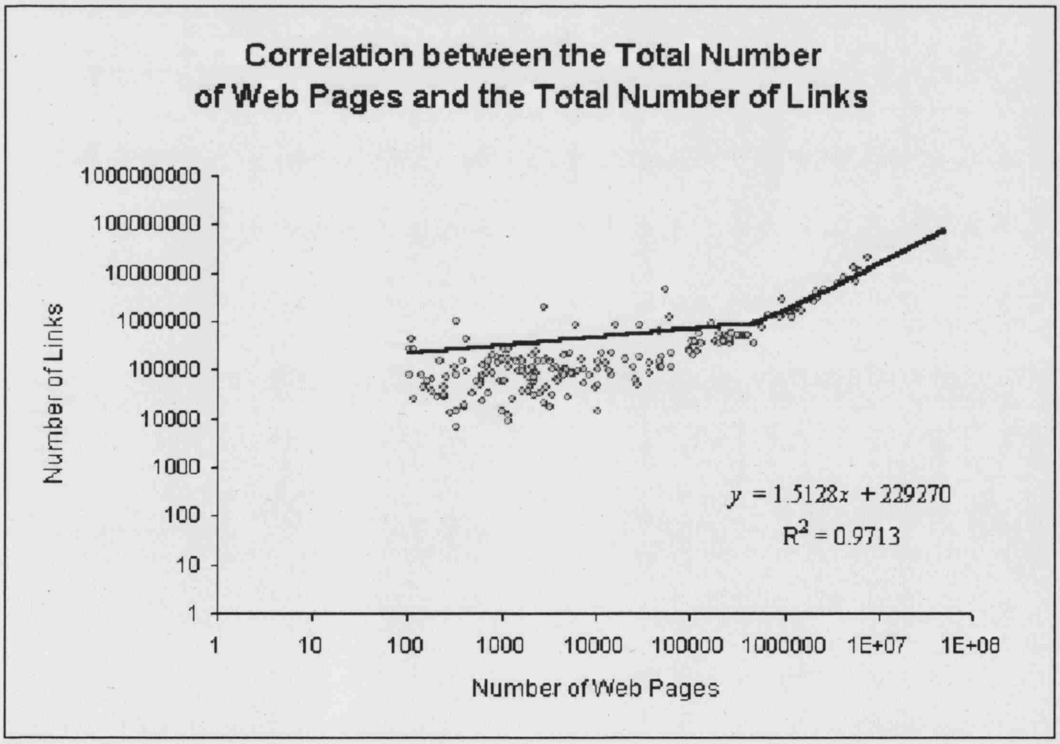
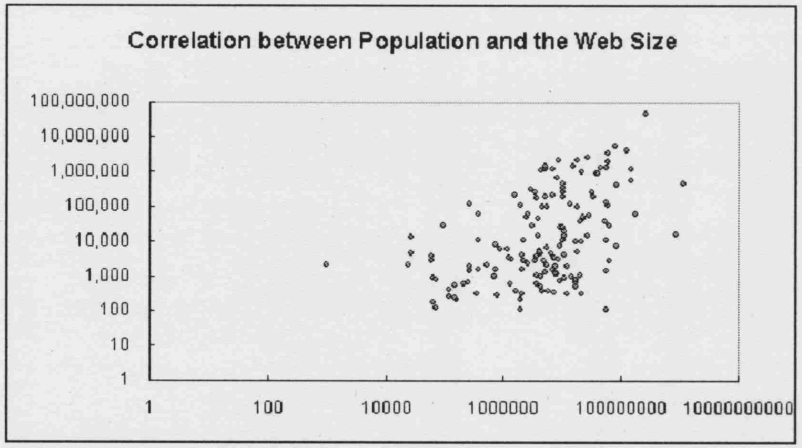
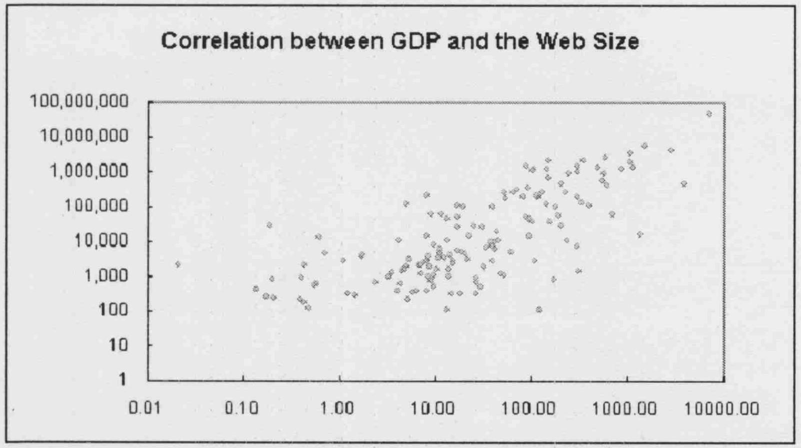


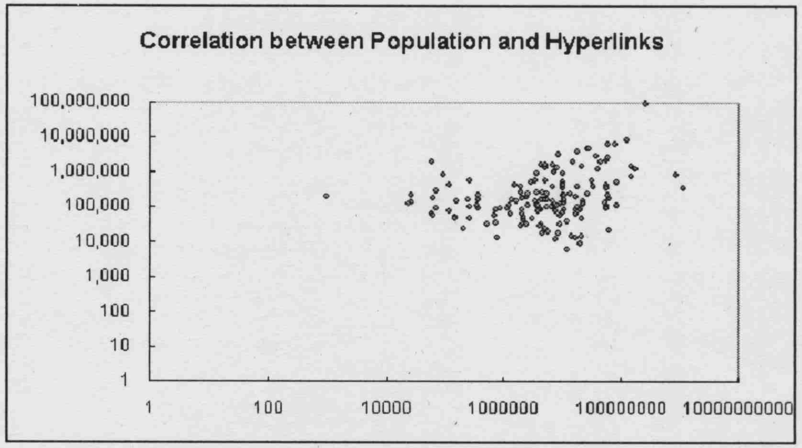
Figure 3.1.2 Correlation between the total number of Web pages and the number of hyperlinks (Shiode and Batty 2000).



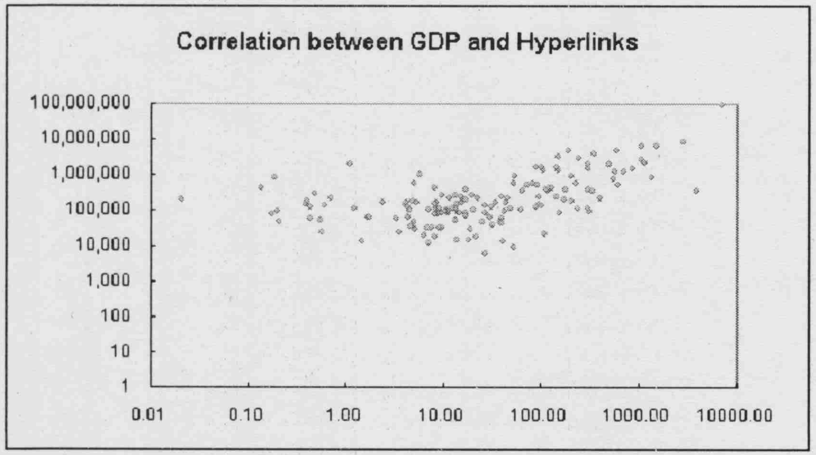
(a) Correlation between population and the Web size (r^2=0.24).



(b) Correlation between GDP and the Web size (r^2=0.74).

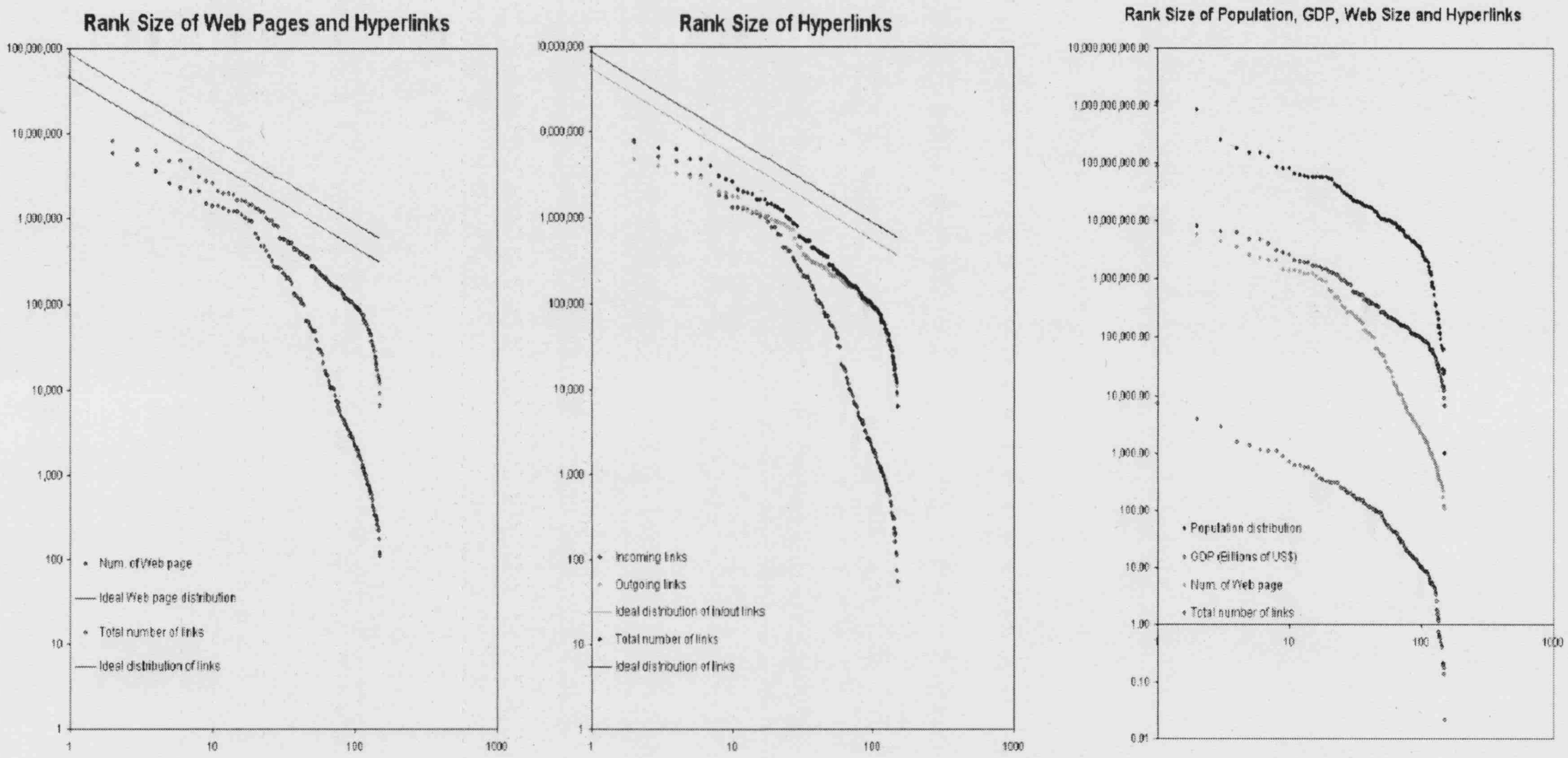


(c) Correlation between population and Hyperlinks (r^2=0.09).



(d) Correlation between GDP and the Hyperlinks (r^2=0.70).

Figure 3.1.3 Correlation between Population, GDP, the total number of Web pages, and the number of hyperlinks. Data Sources: AltaVista (1998), IMF World Outlook (1999); graphs reproduced from Shiode and Batty (2000).



(a) (b) (c)

Figure 3.1.4 Rank-size data, and power law relationships governing Web size (from left to right): (a) Web size and the total number of links; (b) incoming, outgoing and total links; (c) population, GDP, Web size and total links (Shiode and Batty 2000).

Surprisingly, none of the distributions follow the classic linear rank-size form for all distributions are concave to the origin. The largest sizes do appear to conform to simple power laws but the smaller sizes would be radically underestimated using these power laws. It is immediately clear from this analysis that the distributions of population and GDP are much closer over their larger size range to rank-size than any of the Web data (Shiode 2003a). The rank-size is classic for the population of the approximately 100 largest countries (out of 151) with GDP the same for over half (75). The smaller sizes of country in these data than those expected from the rank-size rule is probably are much due to unusual boundaries as to higher growth rates amongst these groups. In contrast, only the first 20 or so domains follow the rank-size when Web page size is examined. It shows a distribution typical for a system undergoing a very rapid growth amongst most of its objects with an implication that as one examines successively through the lower ranks, growth rates would rise inexorably (Simon 1955, Shiode and Batty 2000). In terms of more mature systems such as population, the notion is consistent with the data and with our intuition (Carroll 1982, Batty 2001, Batty and Shiode 2003).

Examining the number of links is more problematic. The total and outgoing links conform strongly to rank-size at least for the largest 100 domains measured by these linkages but incoming links is the least like rank-size of any data in this analysis. Again, there is a plausible explanation that outgoing links constitute much of the links in Web pages to date, and these tend to reflect our perceptions of size while incoming links reflect our ability to link with others (Broder *et al.* 2000, Shiode and Batty 2000). They are quite different and asymmetric in that we tend to know more than proportionately about bigger places than the smaller. This too should change as systems mature. Table 3.1.1 shows the rank-size relations fitted to these six distributions.

Table 3.1.1 Comparison of the rank-size curves of population, GDP, Web and hyperlinks.

Distribution	Intercept log K	Slope $-q$	Correlation r^2	$P'(1)/P(1)$
No. Web Pages	21.22	2.91	0.90	35.84
Total Links	18.60	1.60	0.92	1.35
Incoming Links	21.48	2.98	0.89	37.28
Outgoing Links	17.83	1.46	0.91	1.03
GDP	11.98	2.18	0.80	22.67
Population	23.39	2.00	0.72	12.64

Table 3.1.1 show a relatively high correlation r^2 for the trend line but in terms of their actual fit, the evidence of primacy in the top-ranked sites for Web data and for GDP, as well as the substantial deviations in the short tail for the Web data, reveal that rank-size is only a theoretical ideal which might be attained in the steady state when all domains have been subjected to growth for a long period (Shiode and Batty 2000). To illustrate these points more clearly, the idealised rank-size distributions for each set of data was calculated, based on $P''(r)= P(1)r^{-1}$ where $P''(r)$ is the idealised value at rank r and $P(1)$ is the largest observed value in the set. This equation generates a straight line on the log-log plots and shows the amount of deviation from the steady state for each set of data. These in fact indicate that the largest sizes do conform well in all cases to rank-size with the shorter tails departing substantially in terms of the slope. Finally, each data set was divided into two ranges in such way that they improve the goodness of fit against their trend lines and was re-fitted with their respective rank-size relations (Table 3.1.2 and Figure 3.1.5).

For instance, the total Web pages at each site were computed from the pure rank-size: the first based on the above equation, the second based on $P'''(r>20)= P''(20)r^{-4.25}$ which better mirrors the data in the lower ranges. The fifth column of Table 3.1.2 shows the weighted ratio between the upper ranks and lower ranks where w_1 and w_2 are the weight of data counted into upper and lower ranks, respectively. These results suggest that there is a substantial change still to work itself out within the World Wide Web as the lower ranked sites gradually grow towards the more mature sites at the upper levels of the range. The temporal transition through which sites change their rank will be discussed later in the context of the network society (Section 6.2).

Table 3.1.2 Comparison of the rank-size curves with bi-part distributions.

Distribution	Slope $-q_1$ for upper ranks	Correlation r^2 for upper ranks	Slope $-q_2$ for lower ranks	Correlation r^2 for lower ranks	w_2q_2 / w_1q_1
No. Web Pages	0.88	0.97	4.25	0.98	31.05
Total Links	0.86	0.97	2.07	0.91	15.47
Incoming Links	1.04	0.98	4.49	0.97	26.30
Outgoing Links	0.78	0.97	1.87	0.88	17.29
GDP	1.22	0.99	3.25	0.80	5.65
Population	1.01	0.91	2.80	0.73	1.31

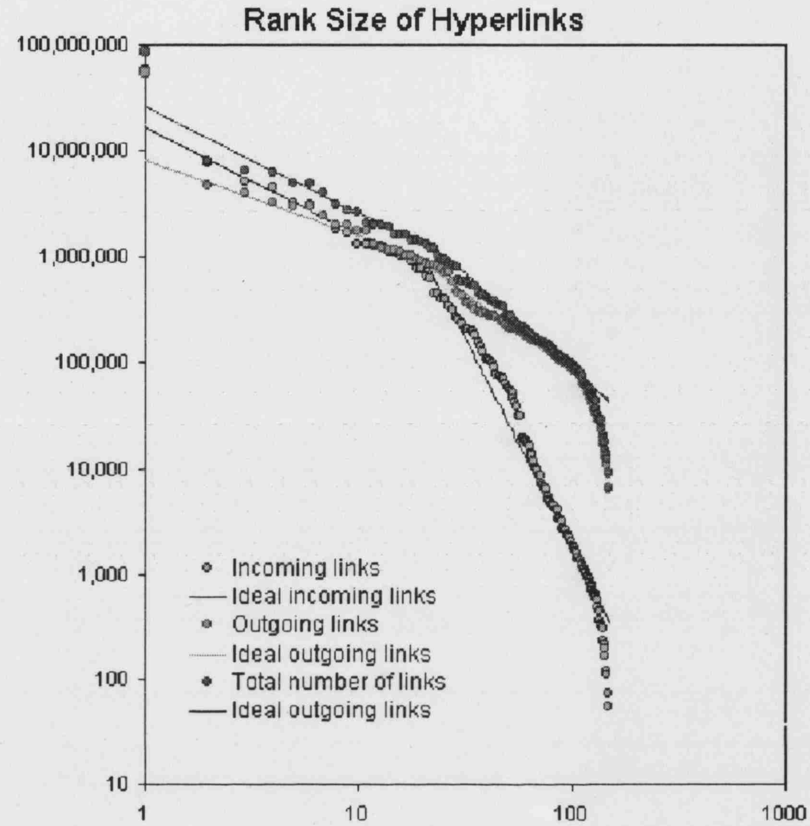


Figure 3.1.5 Applying an ideal rank size trend lines with a bent (Shiode and Batty 2000).

3.1.5 Summary of Findings on the Scaling Tendency of Web Space

This section explored the same dataset of Web domains used in Section 2.3, and it analysed it from the viewpoint of size distributions. The correlation found between the size of the Web and the global population was low (Figure 3.1.2a) but that between the Web and GDP was much higher with an r^2 at over 70 percent (Figure 3.1.2b), confirming our general intuition that the economic development of a domain is all the more important in explaining its size. As the global information society matures, the size of the Web is expected to reflect the population size of nations much more than it does at present although by then, there will be other specialist Web-like resources which will depend more on the economy than on indicators of demographic size.

Moreover, as the overall rank-size patterns of the Web, its links, and GDP are quite similar, it is perhaps reasonable to conclude that the distribution of Web domains and their links broadly reflects existing economic activity patterns, albeit differences in the distribution pattern of population and Web services. In addition, the Web-based services are expected to be carried out at locations remote from places at which these services are initially registered, and such differences would likely be reflected in the flows of information between domains – the trade in information between countries. Although the link data used in this section contains this, we have not yet been able to explore the patterns contained therein in ways that would confirm this speculation.

The power law relations that were explained in Section 3.1.2 and examined with the web data in Sections 3.1.3 and 3.1.4 all display the tendency for the number of small events – Web sizes, links, populations, and GDP of small countries – to be less than what the rank-size rule predicts but with Simon's (1955) model, this can easily be explained by the smaller domains having not yet reached maturity (Shiode and Batty 2000). This study did not go as far as to compute growth rates or exponents for every level of rank but it did illustrate the plausibility of the hypothesis that the largest domains approximate the rank-size rule while the smaller domains are growing towards this steady state. The differences in power law computed between these two sets would confirm this notion, which requires much better data at more than one point in time. As this analysis is based on a single time-point, it can be regarded as a first step for a spatio-temporal analysis comprising multiple time-points; which would help us interpret how Web space is developing. There are many other issues and possibilities that need to be addressed herewith. In addition to the implementation of a time-series analysis, we need to clarify the definition of domains in spatial as well as categorical terms, and we also need to consider a suitable level of spatial and temporal aggregations.

A major problem is still the definition of the domains that are primarily associated with firms and organisations in the United States. In particular, super-national level domains such as "*com*" and "*org*" require careful estimation as to the extent of their contribution by the US firms and those based in other countries. Some of these large domains were omitted in this study, but their inclusion would significantly alter the value of Web size assigned to the US domain, which in turn, would cause significant changes to the distributions. However the overall pattern of the rank-size distribution of Web space would not be markedly altered by such changes, and an essential next step is to see how robust this kind of analysis is to changes in time (See Havlin 1995, Stanley *et al.* 1996, Batty and Shiode 2003 for discussions on the robustness of rank-size system over time). Only then will we be in a position to make some tentative predictions as to the future form of cyberspace.

Table 3.1.3 The full data set used for the analysis of the scaling tendency of the Web space (Shiode and Batty 2000).

#	Country	Domain	Population	GDP (billions US$)	Web Site Sizes	Incoming Links	Outgoing Links	Total Number of Links
1	Albania	al	1626315	4.077	375	110	149394	149476
2	American Samoa	as	156349	0.396	222	321	148460	148712
3	Andorra	ad	61599	1.116	2793	1786	1920834	1921655
4	Antigua and Barbuda	ag	64794	0.409	871	742	179422	179789
5	Argentina	ar	32712930	304.500	190015	178108	256908	375749
6	Armenia	am	3611700	8.408	3818	2364	106967	108637
7	Australia	au	17661468	347.394	2095633	3009484	1985130	3938057
8	Austria	at	7914127	150.804	660072	751277	867942	1325284
9	Azerbaijan	az	7021178	10.982	3494	1396	100743	101974
10	Bahamas	bs	264175	4.596	1495	1215	95496	96303
11	Bahrain	bh	520653	7.026	2185	1969	28780	30325
12	Barbados	bb	255200	2.464	713	682	157070	157577
13	Belarus	by	10222649	45.791	11397	15974	203379	213927
14	Belgium	be	9967378	204.086	474097	608335	562847	929725
15	Belize	bz	205000	0.588	624	194	23112	23277
16	Benin	bj	4304000	9.893	493	305	31934	32070
17	Bermuda	bm	61220	1.700	3716	3913	61730	63590
18	Bolivia	bo	6420792	20.290	4524	3307	97892	99823
19	Bosnia and Herzegowina	ba	3707000	4.465	632	1001	123422	124039
20	Botswana	bw	1326796	4.364	594	648	59167	59515
21	Brazil	br	150367000	874.490	1198581	1115385	707571	1419328
22	Brunei Darussalam	bn	267800	5.121	2008	1379	44632	45601
23	Bulgaria	bg	8990741	31.060	25610	18049	106245	116986
24	Burkina Faso	bf	9190791	9.182	737	567	32289	32674
25	Cambodia	kh	5816469	6.460	401	602	18888	19274
26	Cameroon	cm	10446409	27.232	926	1024	132663	132989
27	Canada	ca	27408898	598.519	2556128	3134643	2889642	4711362
28	Chile	cl	13599428	146.024	121839	98679	190051	245506
29	China	cn	1136429638	3843.540	468891	199439	202075	354751
30	Colombia	co	27837932	194.264	56175	70752	4668007	4712344
31	Congo	cg	1909248	13.678	109	118	267335	267429
32	Costa Rica	cr	2488749	17.462	50829	77500	139842	190847
33	Cote D'ivoire	ci	10815694	22.869	14827	11528	209686	216264
34	Croatia (Hrvatska)	hr	4511000	19.501	97246	100077	210361	269414
35	Cuba	cu	10743694	14.348	4320	1976	85228	86187
36	Cyprus	cy	725000	9.829	8496	9840	72726	79333
37	Czech Republic	cz	10328017	91.811	358713	441230	251110	517527
38	Denmark	dk	5225689	105.800	1189357	995864	921833	1282025
39	Djibouti	dj	62892	0.444	170	54	58955	58997
40	Dominica	dm	71183	0.200	788	1141	87674	88317
41	Dominican Republic	do	5545741	34.383	7136	8395	162961	167768
42	Ecuador	ec	10740799	44.888	20504	16966	154140	162723
43	Egypt	eg	55163000	235.864	10685	6260	103236	107024
44	El Salvador	sv	4845588	15.535	2890	2688	167207	168919
45	Estonia	ee	1570432	8.149	220819	156117	331001	414766
46	Fiji	fj	715593	4.697	1615	2553	34318	36069
47	Finland	fi	5067620	89.920	1477440	1277732	1093688	1618361
48	France	fr	57526521	1141.601	1384662	1244540	1287696	2064790
49	Georgia	ge	5400841	7.067	2181	2003	96716	97869
50	Germany	de	79364504	1499.874	5760926	5107297	3913423	6432124
51	Ghana	gh	12296081	31.736	1907	2633	35140	36900
52	Greece	gr	10313687	119.533	200666	201923	236204	352358
53	Guatemala	gt	9197351	40.306	7465	6346	51581	55675
54	Guyana	gy	758619	1.487	291	323	12804	13058
55	Holy See (Vatican City)	va	1000	0.021	2107	1209	195522	196640
56	Honduras	hn	4248561	11.187	4682	3961	78150	80570
57	Hong Kong	hk	6686000	113.900	223465	249257	203407	379422
58	Hungary	hu	10323708	64.480	265079	231202	207848	339331
59	Iceland	is	261103	5.036	125834	141512	461785	541806
60	India	in	849638000	1358.980	16620	18741	809657	821241
61	Indonesia	id	179247783	695.034	61010	72207	1158235	1208494
62	Iran	ir	55837163	316.797	1511	1776	89041	90010
63	Ireland	ie	3525719	54.794	172217	197141	839345	946776
64	Israel	il	5123500	82.722	200358	332290	361450	586886
65	Italy	it	57746163	1055.144	2042109	1672011	1731187	2567980
66	Jamaica	jm	2392130	7.773	2522	3112	30229	32504
67	Japan	jp	124451938	2811.027	4291142	7443431	2920306	8024460

Table 3.1.3 *contd.*

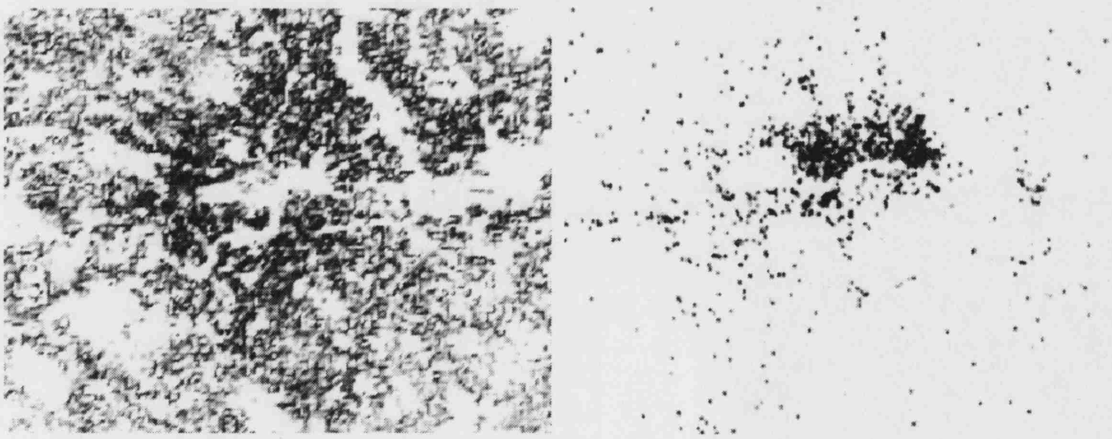
#	Country	Domain	Population	GDP (billions US$)	Web Site Sizes	Incoming Links	Outgoing Links	Total Number of Links
68	Jordan	jo	4012000	17.453	5610	4531	82450	85549
69	Kazakhstan	kz	16721113	40.900	10331	4395	10788	13502
70	Kenya	ke	21443636	38.573	10157	17649	33661	44326
71	Korea, Republic of	kr	43663405	500.410	1325365	1828271	898557	1952830
72	Kuwait	kw	2142600	39.703	2926	2664	40623	42452
73	Kyrgyzstan	kg	4451824	8.300	397	473	16823	17161
74	Latvia	lv	2631567	9.060	62736	52721	79765	108607
75	Lebanon	lb	2126325	13.390	10708	13075	41332	49964
76	Liechtenstein	li	27714	0.630	12735	19151	121769	132115
77	Lithuania	lt	3741671	13.480	48447	50535	83938	113038
78	Luxembourg	lu	378400	11.770	62546	71769	170616	219198
79	Macedonia	mk	2055997	1.762	4053	4354	57232	60100
80	Madagascar	mg	7603790	8.978	1939	1323	72981	73818
81	Malaysia	my	18180853	177.544	103451	123586	286836	371280
82	Malta	mt	362977	4.280	10681	13380	149251	155736
83	Mauritius	mu	1168256	11.137	6356	4741	89628	93531
84	Mexico	mx	81249645	611.007	410630	398925	298736	518686
85	Micronesia	fm	118000	0.176	259	438	72631	72992
86	Moldova	md	4360475	8.607	989	1379	157999	159135
87	Monaco	mc	27063	0.721	4617	5329	206497	209522
88	Mongolia	mn	2043400	4.862	1543	939	171934	172360
89	Morocco	ma	26069000	95.438	14828	8509	224195	230475
90	Mozambique	mz	14548400	13.762	998	626	14242	14661
91	Namibia	na	1409920	5.482	3188	3261	153192	155413
92	Nepal	np	17143503	27.265	680	349	82621	82833
93	Netherlands	nl	15184138	299.095	1400750	1226612	1176283	1872236
94	New Zealand	nz	3442500	53.018	264700	398964	310160	559471
95	Nicaragua	ni	3745031	8.192	15129	9888	68176	74510
96	Niger	ne	7248100	5.731	334	299	1004784	1004990
97	Nigeria	ng	55670055	120.614	114	161	441276	441391
98	Norway	no	4286401	103.092	1107890	1100720	1133883	1577234
99	Oman	om	2017591	14.952	330	230	79493	79658
100	Pakistan	pk	84253644	304.174	7420	9432	99234	105773
101	Panama	pa	2562922	15.703	2313	2579	243978	245467
102	Papua New Guinea	pg	3727250	9.733	1053	1114	272317	273152
103	Paraguay	py	4039165	19.016	4978	6773	23700	28320
104	Peru	pe	21998261	93.864	47752	44862	124141	153965
105	Philippines	ph	62868212	203.715	29752	40649	153491	179229
106	Poland	pl	38309226	246.790	941280	882854	2365486	2752733
107	Portugal	pt	9845900	130.311	259240	265625	282969	421907
108	Qatar	qa	369079	10.480	1670	1059	93787	94582
109	Romania	ro	22788969	90.536	50182	54944	84292	118744
110	Russian Federation	ru	148310174	552.555	584276	635463	364514	783502
111	Saint Lucia	lc	148183	0.550	581	576	49691	50078
112	San Marino	sm	23576	0.439	2122	2158	115388	116852
113	Sao Tome And Principe	st	117504	0.136	423	768	431341	431931
114	Saudi Arabia	sa	17119000	175.300	794	633	195952	196385
115	Senegal	sn	6896808	13.837	1682	1795	145966	146988
116	Seychelles	sc	72254	0.480	119	116	273872	273985
117	Singapore	sg	2873800	72.031	321030	303417	294290	516817
118	Slovakia	sk	5318178	40.511	99801	108172	167214	237443
119	Slovenia	si	1990623	16.997	115226	105645	336572	392241
120	South Africa	za	30986920	226.646	270970	437548	271843	570861
121	Spain	es	39141219	559.351	904287	761457	748917	1168910
122	Sri Lanka	lk	17619000	63.510	4906	6577	99960	103704
123	Suriname	sr	354860	1.231	309	205	111813	111930
124	Swaziland	sz	681059	3.337	1040	2247	55313	56937
125	Sweden	se	8692013	152.076	2237539	2350221	1707388	3023385
126	Switzerland	ch	6875364	147.654	1217077	1016403	1027583	1617408
127	Taiwan	tw	20878000	298.500	987654	1278921	703337	1429031
128	Tajikistan	tj	5092603	3.622	1314	1567	22843	24215
129	Tanzania	tz	21733000	18.294	327	876	13880	14608
130	Thailand	th	57760000	405.201	111247	91079	152463	206536
131	Togo	tg	1949493	5.149	217	73	28142	28186
132	Tonga	to	93049	0.192	29149	62087	785745	841328
133	Trinidad And Tobago	tt	1227443	12.342	3501	4292	102605	105806
134	Tunisia	tn	7909555	49.836	1184	913	112983	113434
135	Turkey	tr	56473035	334.941	130324	205634	176272	340697
136	Turkmenistan	tm	3522717	8.269	2791	3260	144939	147542
137	Uganda	ug	16671705	30.618	531	953	58501	59168
138	Ukraine	ua	51801907	102.948	36944	56573	96283	139110
139	United Arab Emirates	ae	862000	42.901	5969	4805	86040	89262
140	United Kingdom	uk	57998400	1064.244	3554483	4497411	3184530	6167812
141	United States	us	258115725	7044.145	45787732	57229750	53917475	86614986
142	Uruguay	uy	3094214	25.511	28432	30477	28068	47901
143	Uzbekistan	uz	19810077	52.344	1149	1309	8624	9115
144	Vanuatu	vu	150165	0.207	241	478	45457	45756
145	Venezuela	ve	20248826	154.581	38043	38768	59248	84680
146	Viet Nam	vn	64375762	111.141	2771	1603	19441	20548
147	Yemen	ye	12301970	27.390	326	315	6239	6446
148	Yugoslavia	yu	10394026	17.000	26419	31582	44396	65735
149	Zambia	zm	7818447	7.239	1193	816	11620	12147
150	Zimbabwe	zw	8687327	22.317	3310	7206	11813	17375

3.2 Rank-Size Distributions in Network Spaces, Web Spaces and Cyber Cities

3.2.1 Exploring the Scaling Tendency of Information Spaces

In the previous section, we compared the rank-size distribution of the Web indices, namely, Web size and hyperlinks, to that of the global population and GDP. The study suggested that the Web is still in its juvenile period and will take some more time to be established as a stable social-economic system (Shiode and Batty 2000). This section studies the rank-size distribution of other information spaces in conjunction with that of their real world equivalent. Assuming that the other information spaces share the same distribution pattern of a rapidly growing system in making, as the Web space exhibited, we will attempt to build a conceptual model that simulates their growth pattern (Shiode 2003).

While each type of information spaces identified in Section 2.1 follows its own unique spatial order, they share one common feature in that their distribution pattern has a comparable scaling tendency as we see in this section. Also, with some extension, we may infer a distance metrics within each space as tested in Section 2.3. These points will be illustrated in the following by elaborating on a portion of each space or one of its numerous sub-spaces that comprises it. As before (Chapter 2), examples will be drawn from each of the three top layers, namely the network space, Web space, and cyber cities.



(a) (b)

FIGURE 3.2.1 (a) Population density distribution in the greater London area, and (b) IP address registry distribution within the same area (as of March 1997) (Shiode 2003).

3.2.2 Rank-size Distribution of the Internet Space

As seen in Section 2.2, the physical structure and the components of computer networks essentially consists of, metaphorically speaking, 'nodes,' 'edges' and 'traffics.' The section (2.2) described how Shiode and Dodge (1999a) investigated the geographical distribution of the registered IP addresses within the United Kingdom. We can compare the results from that study to the distribution pattern of their equivalent in the real space, i.e. the population distribution. Figures 3.2.1(a) and 3.2.1(b) respectively show the population density and the IP address block density of the greater London area by postcode zones. The difference between the two maps is evident in that the IP address blocks are registered only at a limited number of places as opposed to the wide distribution of population, and the focal points of the two maps are also clearly different. It shows a particularly strong concentration of IP address blocks in the West-end part of London.

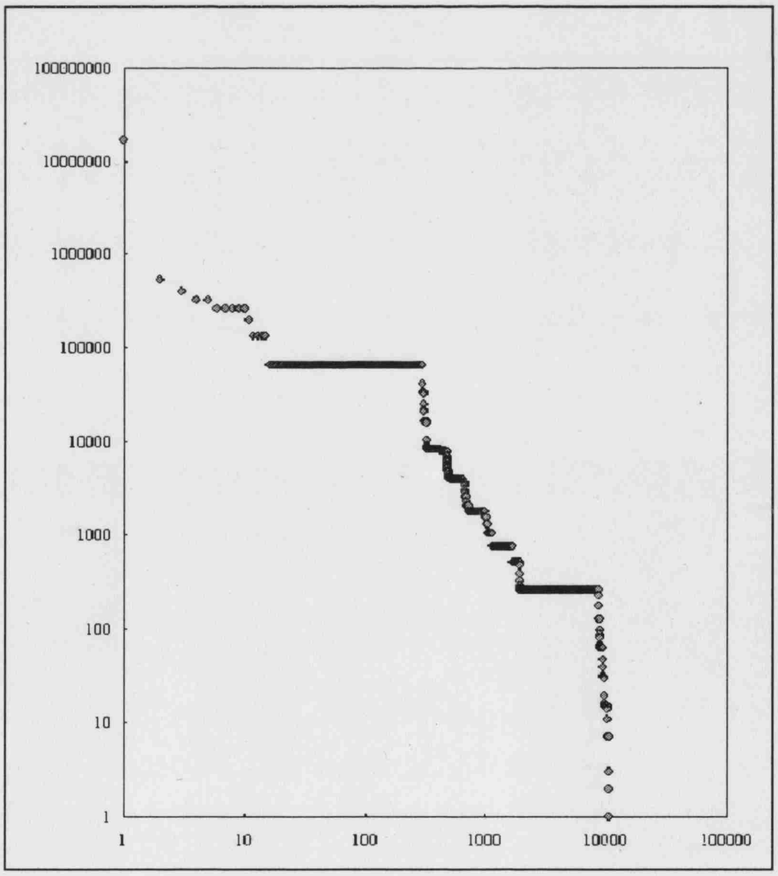


Figure 3.2.2 Rank-size plot of IP address blocks in the UK (Shiode 2003a).

Sheppard *et al.* (1999) and Malecki and Gorman (2001) both suggest that there is an indication that ICT networks are continuously converging, and they are still based on the real geography; nevertheless, as seen in Figure 3.2.1, they possess their own momentum and geography which separate these spaces from the real world. Figure 3.2.2 shows the rank-size plot for the IP address blocks registered at each postcode zone within the United Kingdom. The flat sections show that more than several locations have the same capacity of IP address blocks registered within its area, suggesting that its geography is uniquely different. However, this peculiar distribution occurs only because IP address blocks mostly come in preset size such as 65536 or 256. Most companies are in fact using only portion of the IP addresses allocated to them; and we can thus assume that the following distribution can be reconfigured by a fitting a trend line that follows the same log-normal distribution.

3.2.3 Rank-size Distribution of the Web: Revisited

As discussed in Section 2.3, nodes, edges and the information exchanged at the level of the Web generally exists in the electronic space, unlike those in the physical network, which are indeed strongly connected to the geography of the real world (Goodchild 2001). In other words, its spatial order is dependent on the number of hops and the overall accessibility to the relevant information.

We can still associate the Web data with those in the real world as we did in Section 3.1. In particular, the geo-statistical distribution of the Web can be directly compared with those of demographic and economic data on nation-to-nation basis. Figure 3.2.3 (overleaf) shows the distribution of the rank size of the four indices discussed in Section 3.1 on the logarithmic scale where the value of each nation-states unit is reflected in the vertical direction and its frequency of occurrence on the horizontal axis.

3.2.4 Rank Size Distribution of Cyber Cities and Cyber Places

As cyber cities shares the basic spatial attributes of 3D space with the real world, it is perhaps more intuitive to compare this type of information space with a real city. The case study in Section 2.5 suggested that they are in fact comparable in their overall growth rate, but different in the detailed structure.

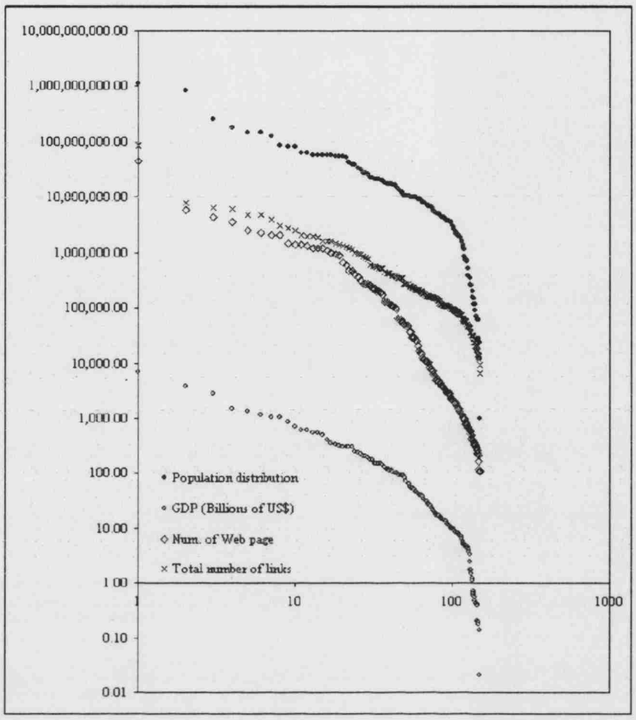


Figure 3.2.3 Rank-size plot for the population, GDP, Web site size and hyperlinks of nation-states (a version of this figure is shown in Figure 3.1.4) (Shiode and Batty 2000).

When a new cyber city first emerges, it develops at a much faster rate than most real cities would, continuously sprawling outwards from the centre (Shiode 1998, 1999b). This, however, is with the exception of a rapidly booming town and a city that is experiencing a high growth of urban sprawl (Shiode and Torrens 2003a, 2003b; also discussed in Section 2.5). Shiode (1998) applied fractal analysis to measure the growth rate of AlphaWorld at its conception. Active Worlds environments including AlphaWorld provide a good example of a popular pseudo-3D environment, as it is arguably the most popular 3D multi-user world and perhaps the only publicly accessible VR environment that is modifiable (Schroeder, Huxor and Smith 2001). The study confirms that the city follows a fractal structure and has developed remarkably within a 14-month period. By February 1998, AlphaWorld was, in terms of its flat area coverage rate, already as dense as the central London area measured by Batty and Longley (1994) (Figure 3.2.4) (Shiode 1998). It is interesting to note, however, that its growth rate flattened soon after that and that its growth rate is now comparable to that of Austin, TX, as we discussed in Section 2.4 (Shiode and Torrens 2003a). This implies

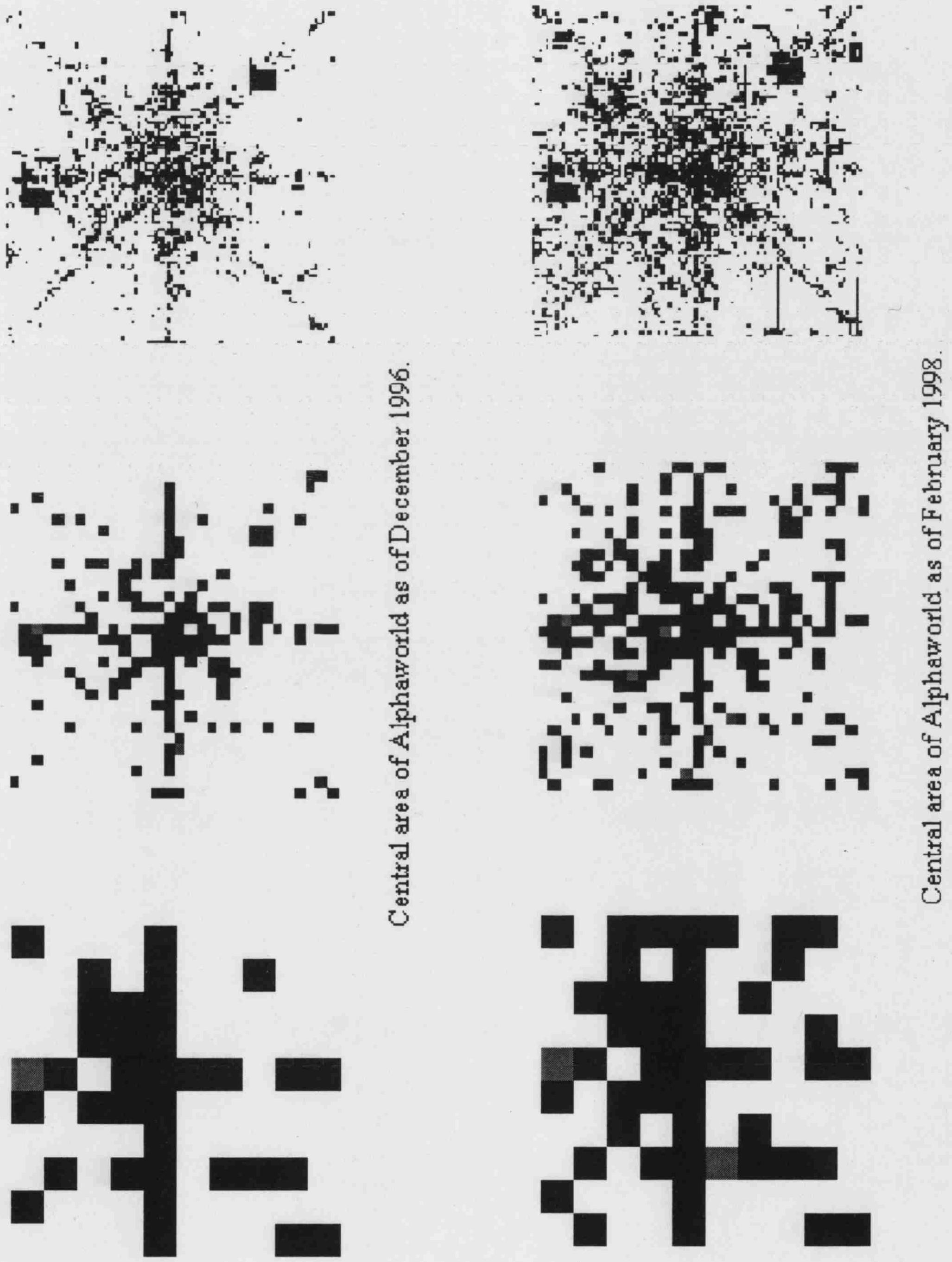


Figure 3.2.4 Visualisation of the central area of AlphaWorld at three different grid scales with pictures from December 1996 and February 1998 (Shiode 1998).

that a cyber city also has its own threshold value for maintaining a self-organising criticality. A rank-size plot (Figure 3.2.5) also confirms that it is comparable to a real world city in terms of its distribution of the block size in the central area, thus suggesting that a cyber city may have an overall distribution pattern similar to those of the real built environment regardless of its density or its age (Shiode 2003a).

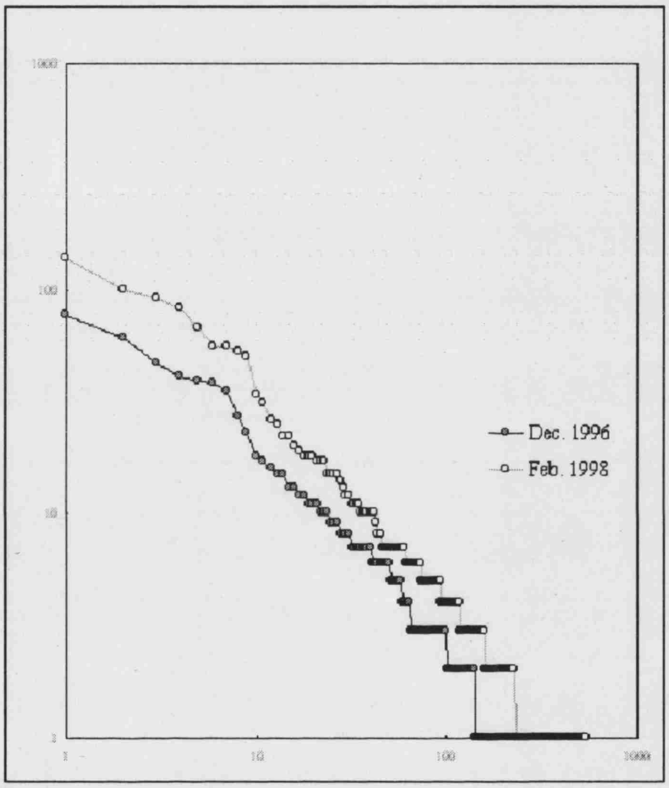


Figure 3.2.5 Rank-size plot for the distribution of block size in the central area of AlphaWorld in December 1996 and February 1998 (Shiode 2003a).

3.3 A Geomorphological Model of Information Spaces

3.3.1 Modelling Information Spaces

Categorisation of information spaces proposed in Section 2.1 suggests that they can be treated as a collection of spaces each of which following a slightly different rules of geometry and physics that govern their spatial attributes. Modelling such variety of spaces requires a flexible and generic framework. It would also require a considerable amount of effort to produce a single model that can describe both the dynamic growth of each space and the relationship among them at the same time. As the temporal data are not available for every space type at this time, this section focuses on building a framework of a model with which we can analyse and simulate the different types of information spaces at a single time point.

In terms of interpreting the spatial attributes of information spaces, we have learned earlier (Section 1.3) that there are already a vast amount of statistical resources as well as numerous theoretical contributions to interpreting subsets of the Internet. Although each research method has much use in its own, particular context, few of them are applicable to simultaneously addressing different types of cyberspaces. Much of this is due to the diversity of information space which requires a quantitative model that would simultaneously accommodate the spatial pattern shown in each space, and a method of transformation that will bind the different spaces together in one layer.

Although they are largely limited to investigating a single type of information space, they still provide some useful insights for addressing the entire range of information spaces in that we can expand from these models. For instance, connectivity and the topological structure of the Web have been studied in conjunction with co-citation analysis and the concept of social network which reflects the 'small world' assumption (Watts and Strogatz 1998, Watts 2000, Barabási 2003) (Section 1.3.4). This connectivity measurement is closely linked to the idea of rank-size rule and power laws describing networks where 'the probability of finding documents with a large number of links is significant, as the network connectivity is dominated by highly connected Web pages' (Albert *et al.* 1999).

It also conforms to the scaling pattern observed among each type of information space (Sections 3.1~3.2). The idea that all information spaces follow the power law to a certain degree gives a useful insight when overlaying the various information spaces on top of one another and when constructing the framework for a single model that could describe the range of such spaces.

Based on these insights, this section proposes a spatial model of information spaces in terms of their morphological structure. A detailed simulation of the growth of information space would be difficult at this time, for we do not quantitatively know the growth rate and spatial characteristics of each space, but we will compare the existing models and aim to extract implications from the application of such models in other incidents.

3.3.2 Adopting the Framework of the Spatial Model from Astrophysics

The overview on rank-size distributions of information spaces discussed in Section 3.2 suggests that, with some reservation, each type of information space comprises of measurable elements whose distribution patterns are comparable to those of their equivalent in the real world. They share a similar scaling pattern with one another, suggesting that we could describe them all with a single model of a social-economic system governed by the same basic scaling tendency.

To this date, a number of morphological models have been developed to capture the distribution pattern of various spatial economic systems. Many of these models have a relatively simple structure but are successful in describing complex scenarios such as the urban growth dynamics and other growth process observed among social-economic phenomena. These models include reactive-diffusion model, Brian Arthur's Positive Feedback model, Schelling's model and Krugman-Page model (Fujita *et al.* 1999). These models would suffice the purpose of introducing the spatial dimension to the simulation. However, in order to explain the explosive growth of information space, we need a model that can also describe a much faster change in the spatial attributes.

Amongst the known social and physical phenomena for which we have sufficient literature and models to interpret them, only few of them have demonstrated the same magnitude of rapid and dynamic evolution pattern that can be compared to that of information spaces that we have witnessed so far. One such example can be found in the growth and the spatial extent of stars and galaxies. If we reflect on how the universe and galaxies have grown in an explosive manner to this date, we realise that a certain degree of commonality exists between the growth pattern of galaxies and that of information spaces.

Obviously, the scale represented by the universe appears to be much greater than that of an information space, and the comparison here is that of a metaphorical debate, but the elastic nature of their spatial and chronological dimensions do show certain degree of similarity. For this reason, we shall turn to astrophysical models. Initially, Groth and Peebles (1977) proposed that the distribution of galaxies could be described by a power-law correlation function

$$\xi(r) = (\frac{r}{r_0})^{-1.8} \qquad (3.3.1)$$

where r_0 is the correlation length of the two-point correlation function ξ (Groth and Peebles 1977). This means that the fluctuation in the galaxy density has a fractal dimension of D = 3 - 1.8 ≈ 1.2 — i.e. the degree of complexity remains statistically constant regardless of scale (Vicsek and Szalay 1987). It was then suggested that the correlation function of the distribution of galaxy clusters also follows a power law of the same slope, but its amplitude was systematically changing with the richness or the number of galaxies per cluster. And because this change in amplitude scales in such way that the mean distance of objects and r_0 remain proportionate, there is no way to tell a map of galaxy from the cluster representation of an urban configuration as long as their fractal dimension coincides with each other.

Taking this interpretation further, we could model the morphological structure of virtually any phenomena by selecting the right fractal dimension and cluster correlation. In the case of information spaces, we may spatially and temporally simulate the dynamic growth regardless of their actual scale or rate of growth and evolution, once the growth rate of each space is found.

3.3.3 Developing a CA-type Astrophysical Model of Information Space

Following the idea that each information space has a fractal-like and scaling pattern of spatial distribution, we will formulate a simple cellular-automaton- type (CA) simulation based on the astrophysical model that generates a scaling distribution. As we do not know the growth rate and spatial characteristics of each space, the model will not produce any results that can be calibrated with the existing data. But we will nonetheless expand on an existing model and aim to extract implications from the application of such model in other incidents.

There is still no 3D-VR equivalent of such simulation model, but we can utilise a simple cellular-automaton type model for this purpose. In particular, we adopt the model proposed by Vicsek and Szalay (1987) which is shown as

$$a(\chi|\chi_j+1)=c\left[-a(\chi)+\sum_{\substack{i,j\subset N\\ i\neq j}}\sum_{l=-1}^{1}a(\chi|\chi_i+l)\right]+f(\chi) \qquad (3.3.3)$$

where i, j ($i, j \cap N$) correspond to the 2D grid and k to the total elapsed time, respectively.

Also, $a(i,j,k)$ is a number attributed to the site (i,j,k) and $R(i,j,k)$ is a random number which, for the sake of simplicity takes on the values 1, -1 with equal probability, corresponding to white noise. Equation (3.3.2) is a generalised form of the cellular-automata in that $a(i,j,k)$ can take any real number. In Vicsek and Szalay model (1987), R represents the initial random density fluctuations in the Universe whereas in our cyberspace simulation, this will be substituted with the social attractiveness of each space. As its distribution is not known, we shall leave it as a random function of white noise, but it can be fitted with any distribution later. We will also assume that site (i,j,k) will form a space if $a(i,j,k) > A$, where A is a constant threshold.

By definition, it is clear that equation (3.3.2) 'correspond to a three- dimensional growth process which advances layer by layer, and the value of the site function $a(i,j,k)$ in the next layer is determined by the average over the five nearest neighbours in the previous layer and the value of the random number $R(i,j,k)$' (Vicsek and Szalay 1987).

We cannot simulate the growth of cyberspace as a whole, for we need to measure the growth rate at each level of cyberspace. However, this model should be fundamentally applicable to each level of space, and we can digest it in the context of multiple information spaces by adding a suffix which indicates the level of space, provided that a distance metric can be inferred for each space. As we saw in the examples, the method of defining a distance metric within the space may vary according to the type of cyberspace. Also, as seen earlier, the scaling trend-line from two different periods shows a constant growth of cyber cities. If we could obtain temporal data for other information spaces and verify their consistency, then this model can be used to simulate the entire cyberspace.

Assuming that we will be able to overcome these obstacles in time, we proceed to build a model based on the generic form of Equation 3.3.2 that provides us with generate a simulated distribution of cyberspace

$$a(\chi|\chi_j+1)=c\left[-a(\chi)+\sum_{\substack{i,j\subset N\\ i\neq j}}\sum_{l=-1}^{1}a(\chi|\chi_i+l)\right]+f(\chi) \quad (3.3.3)$$

Here, i and j are represent the different types of cyberspace, f is a residual term corresponding to a random walk, and c is a constant. The apparent problem here is that it is impossible to make one layer contagious to another unless we know the growth rate of each space and their relative positions. As such we will, in the following simulation, assume that $i = j = 1$ and carry out the experiment for a single cyberspace type.

The implications obtained from Vicsek's model are as follows. If the fractal dimension remains statistically constant, the spatial and temporal explosion simulated by the model will continuously maintain its frequency and will produce a staggering growth of power series. In other words, the above model predicts that, unlike some other social phenomena that reaches mutual equilibrium—mainly due to capacity limit—the information spaces are likely to maintain its dynamic growth rate unless a new constraint external to the system of cyberspace is introduced.

In practice, however, there are certain elements that may act as a constraint on the growth of cyberspace. These include the capacity load within networks and the maximum digit allowed by the Internet protocol of the time which will be continuously improved as the demand grows higher. To what extent these factors affect the growth of cyberspace in long-term is yet to be measured, but within a short period, there is few physical constraints that would prevent information spaces from growing.

Simulating the Spatial Distribution in an Information Space

The sample data exhibited in Figures 3.2.2, 3.2.3, and 3.2.5 consistently indicated a slope $-q$ between 1.4 and 1.6. Using these values as the threshold A for generating the spaces, we could conduct a simulation experiment of information space using the above model. After several iterations of running the simulation model, a rank-size plot for the distribution of our simulated information spaces emerged (Figure 3.3.1).

Technically speaking, the results could be visualised in a multi-dimensional grid space. An example of such projection is shown in Figure 3.3.2. However, the resulting image is quite dissimilar from the map shown in Figure 3.2.4, which has the same frequency of occurrence for the cells but may be affected by some other factors (Shiode and Torrens 2003a, 2003b). Once this underlying force for cyberspace formation is revealed, we can simulate a full scale simulation of the growth and distribution pattern of information spaces.

Apparently, we need to extract the precise measurement of the scaling slope of each cyberspace and also measure their growth rate before making any decisive prediction—we

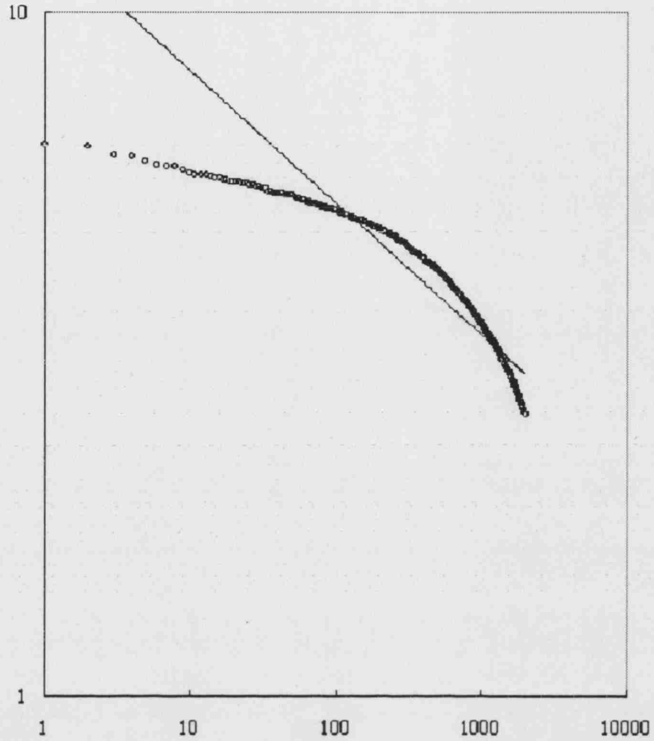


FIGURE 3.3.1 Rank-size plot for the distribution of simulated cyberspace.

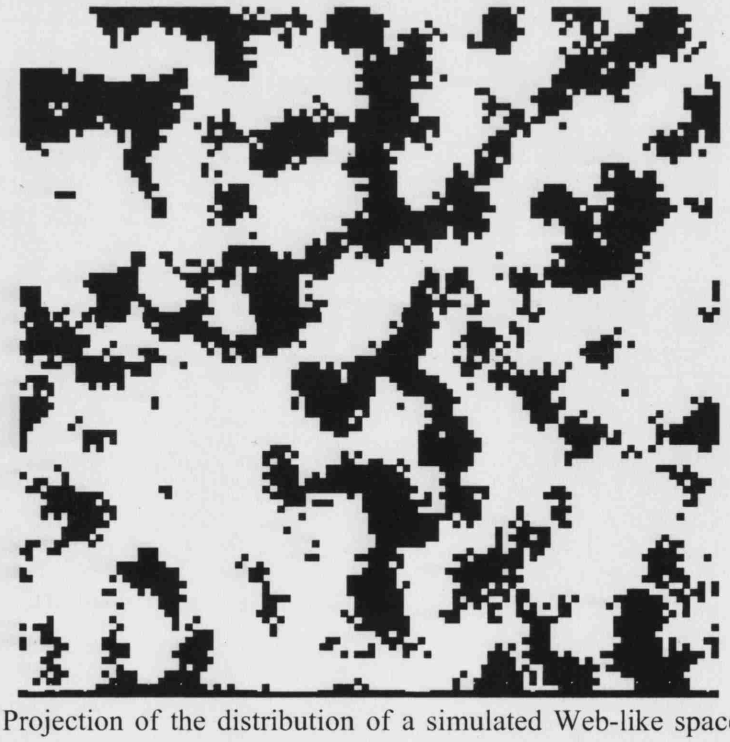


FIGURE 3.3.2. Projection of the distribution of a simulated Web-like space on to a grid cell of 100 by 100.

will also need to take account of the fact that the number of different types of cyberspace may increase in time, and that the entire system would become even more complex; at which point the spatial variable would further increase.

3.3.4 Summary of Findings on Modelling and Simulating Information Space

This section proposed a preliminary framework for modelling the different types of information spaces in a single format. The spaces included in the model were essentially an offspring of the rapidly growing ICT network, namely the physical infrastructure of the computer networks, topological structure comprising the information space, and pseudo-3D worlds of cyber cities. Although they had a different notion of distance and accessibility, they exhibited a similar scaling tendency, which held the key to the formation of the simulation model. Based on an astrophysical model, we developed a cellular-automaton type model that generated the scaling distribution which conformed to the patterns observed among the examples discussed in Chapter 2. The patterns obtained through the simulation, although not yet verified, shows how the distributions found in a cyberspace can be projected onto a 2D grid space and simulated with the use of a relatively simple model. The results are still to be evaluated by comparing them against the existing spaces; in fact, the proposition of the models forms only the first avenue of a long quest for an effective model of information space which we hope to develop in due course.

As far as the visual representation is concerned, we can utilise the existing GIS software packages by projecting everything onto a single layer and separating the elements from different network structures with the attribute labelling (Padmanabhan and Subramanian 2001, Shiode 2001b, Fabrikant 2003, Wang *et al.* 2003). Combined with a conventional spatial interaction model, this would suffice the demand for visualising the linkage between the different layers of information spaces. The main obstacle is to transform the various types of information space into a single layer of visible, Euclidian space.

There are some issues regarding the structure of this model. First and foremost, it does not incorporate the interaction between the adjacent layers; e.g. the physical network of Internet space is treated separately from the Web space, and so forth. While this discreteness helps the formation of a single model that covers the range of information spaces, it also restricts us to generate a simulation that considers the interaction between different types of information spaces.

Also, it needs adjustment to its variable N when a new type of information space emerges at a given time k+1. In terms of maintaining the same index from time k, we would prefer to assign a new number to the newly emerged information space, but this may also invite confusion as it may not coincide with their spatial order among the ranks of the physical versus metaphorical space. As such, the model would require need to be treated continuously over the spatial dimension

$$a(\chi_{j+1}) = c\left[-a(\chi) + \iint a(\chi_{i+1})\right] + f(\chi) \qquad (3.3.4)$$

At the moment, all information spaces are continuously developing at a rapid speed, and they are becoming more and more complex as they absorb more resources and information. It is an uneven, asymmetric process of multi-polarisation rather than a uniform decentralisation, and more complication than simplification. It is conceivable that, in the very near future, most of the urban population in the western nations would start using the Internet in their urban life, consciously or not. In order to retrieve information and to express themselves, each user would need to depend more on its information services — the Web, newsgroups, online chat rooms and video conferencing and whatever virtual environments and services that will emerge from there.

When the current generation of information spaces first emerged, they did not largely substitute for the conventional service of the entity, but complemented it and generated new types of demands. Similarly, when these spaces evolve and perhaps yield to the formation of new generation of cyberspaces, they would not completely replace the existing services, but are more likely to be added to their predecessors and provide different mode of services. We may end up with a variety of modes and spaces allotted for different activities.

In fact, if we abide by the present principle of *laissez-faire*, the Internet and its various information spaces would eventually form a massive labyrinth of miscellaneous data to which we would be forced to adjust ourselves in return for the information dependent urban lives. It is therefore vital to analyse and model information spaces to help interpreting their extent and growth which may contribute to preventing further complication of information spaces and building more efficient IT services.

Interlude

The preceding chapters focused on the ways to interpret the geography of information spaces. Their primary goal was to understand the similarity and the difference in spatial attributes observed among the range of information spaces, and between the real and the virtual worlds. They illustrate, if not comprehensively, a picture of the structural layout and the growth dynamics of the various spaces. The scaling tendency of their spatial distribution was also studied in the attempt to model their spatial patterns. From what we observed, we can conclude that each category of information space is rapidly expanding in its size as well as the number of elements contained within; that is, despite the distinctive differences amongst the notion of distance in each space as well as the adjacency to the neighbours and their immediate vicinity.

Rapid growth in the size of information spaces and the number of their users implies that they can be utilised as a vehicle to promote a range of online applications that can be offered to a wider audience. The notion of utilising cyberspace for a variety of social-economic applications has been known for some time (Benedikt 1991, Mitchell 1995, Schroeder 1996, 2002), but we have yet to witness the development of such applications to their full extent. For instance, there are a variety of online applications (e.g. online retailing and auction activities such as *Amazon.com* or *eBay.com*, online multimedia communications such as IP phones, and music and video contents streaming). While many of them help us improve the level of accessibility to and the amount of opportunity for the various social-economic activities, much of them are aimed at complementing and replacing what was already available in the real world. In other words, we could argue that the true utilisation of the flexible nature of information space is yet to be explored, especially when considering its geo-morphology.

The question then is: *what would be an effective way to utilise these spaces to our benefit? In particular, how can we utilise the flexible and dynamic nature of information spaces, along with its ability to expand and develop rapidly? What kind of applications can make the best use of such unique features of information spaces and use it towards something that may be impossible or costly in the real world?*

The following two chapters discuss precisely that. They comprise a series of case studies and projects on information spaces I have led and have been involved in during my stay at University College London. Based on three separate case studies, Chapter 4 discusses the possible application of the dynamic and interactive nature of information space towards the enhancement of our aesthetic and cultural experiences. The case studies respectively focus on (1) creation of a dynamic and customised art space (Section 4.1), (2) use of the interactive space for enriching our aesthetic and learning experience (Section 4.2), and (3) supporting online learning experience though the construction of virtual 3D cultural and heritage sites (Section 4.3). Chapter 5, on the other hand, takes on the topic of urban planning as a subject for cyberspace applications. It discusses (1) the utilisation of information space as a medium for 3D city modelling (Section 5.1), (2) construction of an online, multi-user, planning-support system (Section 5.2), and (3) the impact of ICT development towards the planning process (Section 5.3).

Chapter 4 can be thought of as an attempt to explore the use of information space for new types of applications and to propose something that was practically impossible in the real world. In contrast, Chapter 5 attempts to support and enhance an existing application for added convenience and possible new insights; by utilising the flexible nature of information space for online communications and data management.

The fact that this study mainly covers the structural and geo-morphological aspect of information spaces suggests that the case studies reported in the subsequent chapters would remain largely as a proto-type study, which would require an extensive amount of work on understanding their social implications and how they can be calibrated to a real world situation. What is being offered in this study is not a sociological narrative of applications in an information space. It is a series of exercise that focuses on utilising the structural side of information spaces that were examined in the preceding chapter, and the readers must understand the extent and limits posed thereby.

CHAPTER IV

INTERACTIVITY IN INFORMATION SPACE

Creating and Sharing a Conceptual Space through Cultural and Art Practice

4. INTERACTIVITY IN INFORMATION SPACE
Creating and Sharing a Conceptual Space through Cultural and Art Practice

This chapter looks at the prospect of enriching our art and cultural experience by utilising the flexible nature of information spaces. In particular, Section 4.1 illustrates the construction of a customised, dynamic art gallery in the virtual environment; whereas Section 4.2 focuses on the enhancement of our aesthetic experience by utilising the multimedia aspect of information spaces. Both of these case studies attempt to generate a new type of application that has been hitherto largely unknown. Section 4.3, on the other hand, looks at the possibility of providing the visual information on lost or destroyed landscapes by constructing the 3D virtual models in the context of art and archaeology. Production of 3D models in a virtual environment has been known for sometime (Day 1994, Delaney 2000, Hudson-Smith *et al.* 2005). What this study provides is the users' ability to examine a series of alternative models, each of which representing a probable option of the past and, thereby, preventing the danger of forcing the users to accept one particular type of reconstruction, which may be nothing more than a speculation.

All three case studies (Sections 4.1~4.3) share the same theme of art and culture, but the use of information spaces as a means of carrying out a new type of application could be much wider and generic in that similar experiences could be achieved in a different context or a discipline. We will elaborate on this point in further detail in Chapter 6.

4.1 Generating a Virtual, Dynamic Museum Environment

4.1.1 Using Information Spaces for a New Type of Art Experience

We are becoming increasingly conscious that information space possesses strong potentials for enhancing our social-economic activities. For instance, its users can gain access to any data distributed on the network at any time and practically from any place (Cairncross 2001). Its spatial order is also distinctive in that, within these spaces, accessibility depends heavily on the topological linkage and that spaces are flexible and easily modifiable (Baker 2001, 2005). Supported by these spatial features as well as their ability to reach out to a wider audience, information spaces have proved their usefulness in various fields including museums and art galleries (Whittle 1997). In fact, a number Web sites and information spaces identify themselves as a "virtual museum" (Shiode 1997). These include:

(1) an ad hoc collection of data, art contents or photographs, typically those in a private possession,
(2) a multimedia data archive of photograph collections as well as text-based and imagery indexes of various art contents that are usually part of a museum collection, and
(3) a full or partial reproduction of the existing museums in the 3D form within which visitors can take a virtual tour, or a pseudo-3D environment such as a 360-degree panoramic scene.

Most of them appear to be treating information space as an alternative medium to disseminate information (Kanoshima and Shiode 1998, Shiode and Kanoshima 1999). Information spaces can indeed provide an effective means of distributing information on the museum resources to the wider public as well as increasing the visibility of museum activities to the society.

However, its flexible spatial nature also allows the museum curators to exhibit their contents in a more dynamic and interactive manner, which was difficult to achieve in the real world. Yet, few of the museums seem to have been successful in utilising the flexible spatial features of cyberspace in such manner so far (Kanoshima 1998).

In addition to offering a social space that provides an effective means of information communications, information space, in this study, is regarded as an entity that allows its virtual visitors to explore their art experience online. By utilising the flexible nature of cyberspace, it proposes a prototype for a new form of virtual museum in which art objects can be dynamically retrieved and the exhibition tailored to reflect the preference of individual visitors. This would allow the virtual visitors to have a more intuitive and closer encounter with the contents of the exhibition with the sequence and combination that meet their taste, thus offering a whole new art experience.

The rest of this section comprises two parts. The first half (Sections 4.1.2~4.1.4) gives a brief review on the existing virtual museums, classifies them into different categories based on their spatial characteristics, and extracts their features and problems as a virtual museum. The second part (Sections 4.1.5~4.1.6) focuses on the utilisation of the spatial characteristics of information space to pursue what has been missing from the existing virtual museums. It proposes a prototype model of a dynamic art gallery that allows its exhibition to be dynamically retrieved and arranged by the visitor's preference. The "museum" discussed here would be therefore clearly distinguishable from the real-world museums but also from the other existing virtual museums.

4.1.2 Definition of the Virtual Museum and Review of the Existing Cases

So far, we have used the term *virtual museum* without any explicit definition. As no fixed definition appears to have been yet established, a number of sites claim to be a virtual museum under their own definition. Consequently, styles, concepts, contents as well as the amount of information offered vary considerably from site to site. These include a variety of data archives and museum information guide sites; which are useful for efficiently retrieving the art objects and collecting the necessary information, and are, by no means negligible. However, as we focus on the realisation of a new type of art experience in cyberspace, this study uses the term "virtual museum" in the following context:

> A virtual museum is the electronic reproduction of an art gallery that contains a collection of electronic artefacts and information resources for public exploration and is subject to the spatial perception of the art gallery to the visitors.

In other words, we use the term as a general reference to a 3D-art gallery electronically constructed within information space. The contents of the exhibition will be primarily of the fine arts; however, the artefacts collected and exhibited need not be limited to visual arts, and the concept discussed here could be applicable to virtual museums of any other types of collection or media.

Searching for the Existing Virtual Museums

There are a number of Web sites that are, or claim to be, related to virtual museums. This can be confirmed by conducting a simple search query for sites that match the words "virtual museum" or "online gallery" on any major search engines. Shiode and Kanoshima (1999) shows that, as of 24 March 1998, there were approximately 1400 of such sites—223 hits by Yahoo (*www.yahoo.com*), 1372 hits by Alta Vista (*www.altavista.com*), and 1425 highly relevant sites on Lycos (*www.lycos.com*). However, many of them were duplicated as various pages of one site referred to both virtual environments and museums. After eliminating these duplicates and other apparently irrelevant data, the list was narrowed down to some 400-museum sites. As of today, in January 2005, there are nearly 900,000 hits on Google (*www.google.com*), although this number includes duplicates and multiple counts for the same site as well as reference to other miscellaneous data.

The majority of the virtual museum sites identified by Shiode and Kanoshima (1999) were either hosted by a real museum or were associated with such entity. In most cases, these sites were designed and maintained by the museum itself or its subcontractor. The contents typically consisted of digital archives of their collections, museum orientation and various other data such as opening hours, entrance fee and directions to the museum. For instance, the Italian National Museum of Science and Technology (*www.museoscienza.org/english/default.html*) has a website that uses the frame design, which was an advanced web application in 1997; and it disseminates information on its history, its collection and other administrative information and resources including a request for comments on future developments. It also has a special section dedicated to the works of Leonardo da Vinci. However, as of December 1997, it had no 3D world to walk through, giving a static impression to the visitors; that is, despite its ambitious title as a "virtual museum"[7]. Web sites featuring a 3D virtual gallery space were still minority in 1997. Among those few sites that offer virtual tours in 3D or pseudo-3D environment, most museums were using one of the following three software technologies (Shiode and Kanoshima 1999): (a) Panoramic viewing by QuickTime VR (QTVR) (*www.apple.com/*), (b) VRML (*www.vrml.org/* and *www.web3d.org/*), or (c) Superscape, Viscape VR plugins[8] (*www.superscape.com/*). In fact, as of March 1998, there were around 130 hits for the combined search on "VRML and museum," and 26 hits on "QTVR and museum" found on Yahoo (*www.yahoo.com*) and AltaVista (*www.altavista.com*).

(a) Pseudo-3D World of QTVR

QTVR gives a 360-degree, panoramic view from a single, fixed spot. By manipulating the keyboards and mouse cursors, visitors can turn around, look up and down or zoom in and out. A good example is the *Musée du Louvre* site (*mistral.culture.fr/louvre/louvrea.htm*).

[7] The Italian National Museum of Science and Technology has revised its website contents since then, and it now offers a VRML-based art gallery; thus evolving to a genuine virtual museum by the definition used in this study.

[8] Superscae has ceased to support its Viscape product line and now specialises in providing online gaming environments and 3D contents for mobile networks.

The QTVR scenes are embedded environment entitled *Voyage Virtuel au Musée du Louvre*, which provides access to 20 panoramic scenes within and around the Louvre museum. The QTVR environment helps give the visitor a better glimpse of the actual museum; however, as it is fixed to a single spot, the visitors cannot proceed to explore other parts of the museum.

(b) 3D Walk-through World of VRML

VRML is *de facto* standard language used for constructing 3D virtual worlds. It also allows the visitors to zoom in and out, tilt, turn, move around and walk through the scene. A few museums, including Hara Art Museum (*www.haramuseum.or.jp/*), have reproduced the real museum in cyberspace either partially or entirely. These worlds are commonly known as either a walk-through virtual environment or a multi-user active world that gives the impression of exploring a genuine 3D space. However, as their primary intention is to imitate the real museum, they appear similar to some 3D CAD models and do not surpass the traditional museums.

(c) 3D SVR World

In addition to the VRML environment, SVR (http://www.superscape.com/) allows the visitors to switch between different levels of resolution. The *State of the Art Gallery* developed by Intel, Co. (http://www.intel.com/english /art/) shows a virtual art gallery of contemporary works. Each piece includes a biographical sketch of the artist and critics from the art experts that are simultaneously shown on the side window. It is also smoother with better visualisation speed and response. The apparent shortcoming is its obscurity and requirements for the special plug-in software.

Other 3D virtual museums use similar technologies including WIRL and 3D Java. Their features were more or less similar to VRML worlds, but were available exclusively with their own plug-in applications.

(d) Other Virtual Museum Sites

Other types of virtual museums include digital archives and museum information sites. Some of the digital archives are quite interesting and useful as they offer the opportunity to display various digital images of works of art that would have otherwise been unpublished.

They are usually maintained by some IT industries or commercial firms and are an index to their virtual on-line exhibition. These are typically a catalogue of their possessions and thence may be unable to offer a fuller aesthetic experience.

Museum information sites are mostly run by the actual museum themselves. Their primary purpose is to distribute the necessary information to the wider public such as the history and the background of the museum, opening hours, contact address, transportation means and admission fees, if any.

Other sites contained more general, miscellaneous pieces of collections. They are typically owned and maintained by individuals, exhibiting their own art pieces and photographs they have taken. Although they are potentially interesting, their purpose is different from those of exploring museums and gives an impression of visiting a private house rather than having a genuine museum experience.

4.1.3 Features and Problems of the Existing Virtual Museums

Focusing on the 3D environment, we extract the features and problems of the existing virtual museums. When compared with traditional museums, this new form of access to the museum information can develop the activity of museum communication for the following reasons.

(a) The Internet can enhance the accessibility to the collection in museums. Visitors can virtually experience the artefacts, whose access to the real museum has been limited by physical distance.

(b) The amount of data available from the museum has been increased considerably. Due to conservation problems and limited floor space available for displays, museums are usually unable to display more than 10-15% of their entire collections. The Internet is one of the most effective media for information dissemination and retrieval.

(c) The collection in the museum becomes available any time on-line. Visitors can access the database any time and, apart from the network congestion, can request the relevant data without any delay.

(d) Visitors can explore the artefact of individual interests. This offers better opportunity for individualised learning, increased interactivity, distance learning and life long learning.

(e) A set of information about a single work of art can be found and referred to with relative ease. The source of the information could be different media including texts, sounds, still images and movies. This integrity is believed to stimulate individual interests. Virtual museums have advantages over texts; bringing vitality, colour and motion to the individual exploration.

We also found the following problems and possible future assignments.

(a) Lack of art experience: With the exception of few 3D virtual galleries, museum sites merely offered an index of collections. In fact, few sites seemed to have paid attention to the aesthetic aspects that we are aware of.

(b) Lack of human contact: The museum web sites are run on server machines and, thus, are incapable of responding to specific questions unless they were sent by e-mail. They would become more interactive and lively once they shift to a multi-user world with the presence of information operator and other visitors.

(c) Immobile exhibition: The contents displayed were as static as those of the real museums. In this sense, museums in the "virtual" settings failed to utilise the spatial benefits of cyberspace, but merely imitating the entity.

4.1.4 Impact of the Use of Cyberspace in Museum Practice

As the publicity of the Internet prevails, more and more museums and galleries use the Internet for introducing their activities such as the notice of special exhibitions, educational programs and other related events. Their electronic presence allows the museums to enhance their visibility and raises public awareness of the importance of their collections (Johnston 1998).

Web sites can also provide materials from the institution's collections as well as research information such as bibliographies and links to other museums and on-line resources

(Johnston and Johnes-Garmil 1997). In fact, museums, universities and other research organisations can build partnerships with the academic communities through the Internet, linking the numerous virtual collections of museums' and universities' databases together (See for instance, the Virtual Heritage Network at *www.virtualheritage.net*, the World Heritage Center, UNESCO at *whc.unesco.org*, and the Electronic Cultural Atlas Initiative at *www.ecai.org*). This enables museum professionals to exchange information and to make a multidisciplinary approach to the object interpretations.

The Internet also promotes the academic use of digitised museum materials for the general public and schools. For example, the Metropolitan Museum of Art (*www.metmuseum.org*) publishes educational and training materials on its core collections that integrate with the American primary and secondary curriculum on the education section of its web site (Howes 1997).

In essence, the Internet is crucial in turning the museum from a repository to an information resource of our cultural heritage. It is also effective in converting the collected information into more dynamic and interactive forms rather than static and authoritative (Worden 1997).

Using Cyberspace for a Virtual Museum Experience

Museums provide resources of extraordinary wealth for the art experience, intellectual stimulation and educational development. As discussed above, the Web is arguably the most effective media ever developed for opening the wisdom of museums to a wider public. However, many of the existing virtual museums are nothing more than a mega-data bank of the collective information relevant to their collections. Some sites are not even distributing any data from their collection, but merely giving administrative information and contacts, yet they claim their contents to be those of *virtual museums*. Lack of source for museum experience results in indifferent attitude and discouragement of visitor's involvement, much less, art experience (Kanoshima 1998, Kanoshima and Shiode 1998).

As the Internet becomes more sophisticated, the method of using cyberspace for museum communication and learning becomes more and more effective and efficient, and so does the interactive elements of cyberspace. Benedikt (1991) has described cyberspace as follows: "its corridors form wherever electricity runs with intelligence. Its chambers bloom wherever data gathers and is stored. Its depths increase with every image or word or number, with every addition, every contribution, of fact or thought."

In fact, our objective of using cyberspace for the museum experience is to provide virtual visitors with access to the collection and information of their choice in a more flexible form. Let us think of cyberspace as virtual environment where visitors can explore the information, manipulate spaces and galleries to investigate their individual interests. The use of this electronic space for the virtual endeavour of museum exploration can promote sufficient entertaining and educational experiences for the virtual visitors. In this context, the development of the virtual museum needs a constructivist approach when designing the visitor interface. The concept of constructivist's approach towards museum experience and learning refers to the museums and galleries as a place that offers not only the database itself but also the usage of database for visitor's own creative learning (Labbett 1995).

Current virtual museums may be claimed as nothing more than a place to exhibit the visual image of artefacts and publish database; but they have the potential to generate interactive space that increases the degree of visitor's involvement towards the constructivist learning support. The use of cyberspace for exploring virtual artefacts and associated information encourages the visitor to inquire the artefact and offers virtual activities using information for a personally driven construction of understanding of the virtual artefacts and information.

Cyberspace can offer effective navigation that would construct creative opportunities of emulating and stimulating human thinking during their endeavour with the museum collection and information. This will add special value to the use of cyberspace for museum practice and, consequently, the museums can respond to the demand from the general public for better interpretation of what the original objects present. In other words, the museums can offer a unique opportunity for their virtual visitors to explore the collections in the individual context.

4.1.5 Constructing a Dynamic Environment for an Art Experience

In this section, we propose a new form of virtual museum environment. As aforementioned, the majority of the existing virtual museums are faithful to the real museums; in fact, they fail to make full use of the spatial features of cyberspace. In some sense, they have not as yet excelled those existing in the physical world.

The virtual museum we propose is a flexible space of art exhibition, dynamically generated within cyberspace. The objective is to customise the form and the structure of the museum according to the visitor's preference. In order to reflect such preferences onto the exhibition and reconstruct the gallery, the museum will be constructed through the following procedures.

Acquisition of Preference Information

Initially, visitors are asked to fill in a form-type-Web page and choose one or more criteria to reflect their preferences. The possible choices are "artist/year," "style of the expression" such as impressionist or pop art, and "theme of the art" such as religion, landscape, still life, and portrait." Visitors may choose multiple options of the same criteria or even select all the options. For instance, suppose a visitor gives the following option: "early and mid-19th century" + "British and French art," "oil painting" + "sketch" and "still life." Once the visitor submits the information, it is passed onto the server as a sequence of queries.

Data Search and Retrieval Based on Multiple Criteria

Upon receiving the preference information, the server decodes it into a string of instances and calls the corresponding Java code that would, in turn, return all the index numbers of the art objects that match the requested combination of preferred attributes. In the case of the above combination, the server searches its database and returns the works of pre-impressionists such as Ingre and Courbet and some early impressionists such as Turner. Based on the requested index numbers, the image data of the corresponding art objects are retrieved and forwarded to the buffer.

Arrangement of the Contents

Once the contents are saved in the buffer, the visitor is asked to give the preference on their arrangement. By default, they are sorted by chronological order; however, the visitor may choose to rearrange them by their themes or the alphabetical order of the artist. The contents are then rearranged and sorted in accordance with the new criterion.

The number and size of the art objects selected determine the size of the exhibition room. By default, there will be, at the most, eight objects in each gallery. If there are more objects, a new gallery will be created adjacent to the former. Here again, the visitors may arrange the pictures in separate rooms according to their preferences. For instance, works of Courbet, the establishing artist of Realism may be assembled in one room while those by the British painter, Turner, may be exhibited in another room.

Creation of the Art Gallery

Finally, a VRML data of gallery is called together with all the digital art objects. The gallery will be assembled into one piece with all the objects in front. The final result will then be sent to the client side and will be enhanced on the visitor's environment. Once the gallery is presented, the visitor will be transported to the centre of the first exhibition room and will be given the opportunity to explore the gallery.

In order to enhance this virtual museum into a multi-user world and allow the visitors to rearrange the art objects within the scene, we will build our virtual museum on top of the VRML server/browser system by Sony Co. called Community Place Bureau and CP Browser. Any results of change or modification made by other visitors will be immediately sent to the CP Bureau running on the server and will be reflected to the scene of every visitor's browser with practically no time delay. This enables the visitor to realise his or her preferable art scene and share the same art experience with others. It would also increase the degree of interactivity and give the presence of the gallery and the sense of being involved into the act of exploration. However, since any user can modify the museum scene, there may be some conflict between the visitors when rearranging the contents and generating the gallery. At the moment, the CP bureau accepts commands from all the clients, once logged in.

As a preliminary study, the interface was designed in HTML and Java-based environment (Shiode and Kanoshima 1999). It has an interactive, query form web page on top, asking the visitors to input their preferences. Again, the basic mechanism is that once the server receives the information, it searches for the relevant data and generates a web page that contains all the images in one page. It is dynamic in that the contents of the page are determined by the visitor and are renewed after every search query. However, it lacks

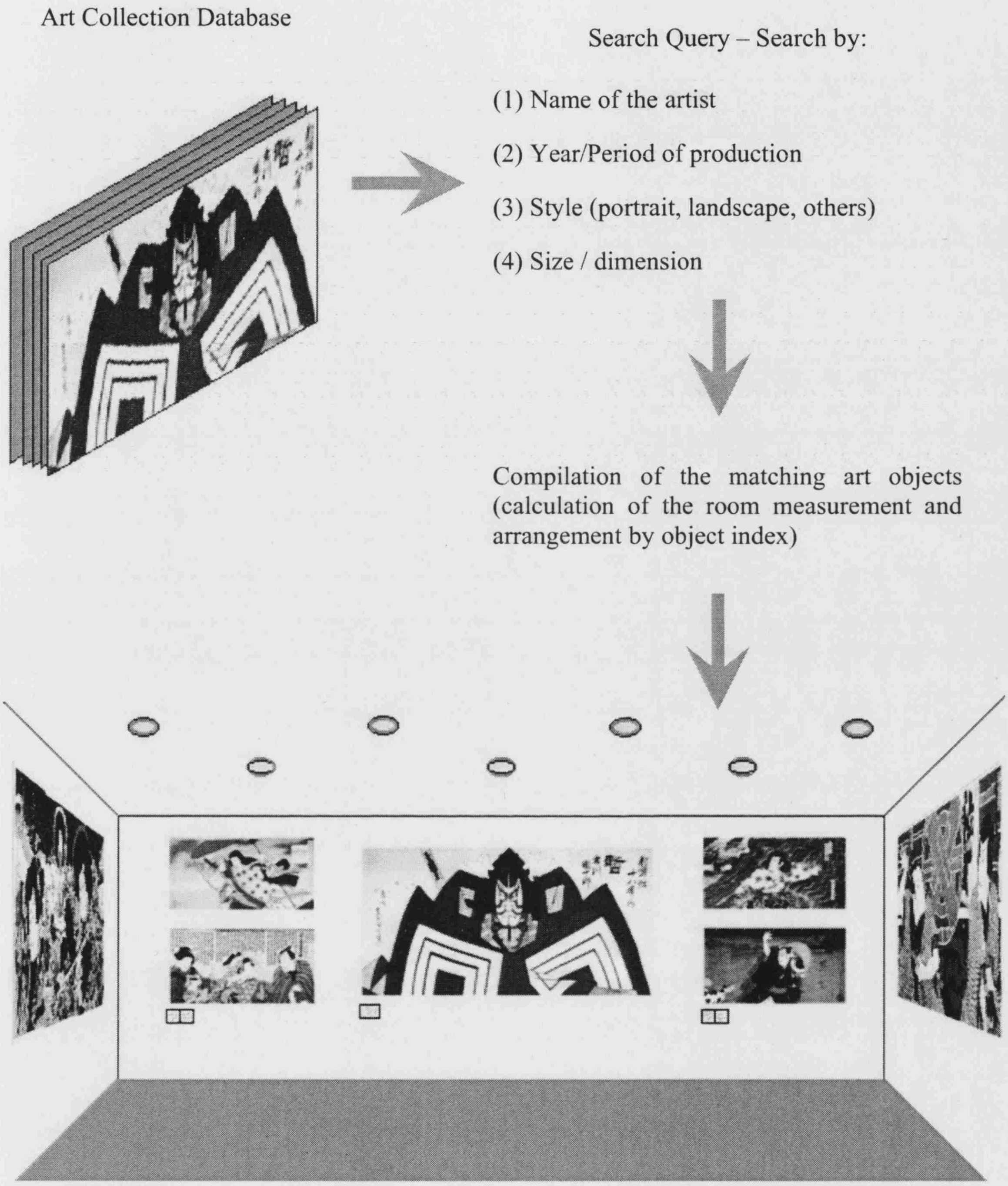


Figure 4.1.1 A schematic diagram of the construction of a dynamic virtual art gallery (Shiode and Kanoshima 1999).

the 3D spatial atmosphere of the museum experience and cannot wipe out the impression of a catalogue.

In the hope that this study will contribute to promoting an art experience in virtual museum settings, Shiode and Kanoshima (1999) started on building a full-3D virtual museum with a database query system. Figure 4.1.1 shows some snapshots of the beta version that was developed then. The images of the traditional Japanese print arts of *ukiyo-e* style used in this study were obtained from Kyoto Institute of Technology, who has a collection of such paintings.

Unfortunately, no museum with a large art collection was interested in such study, and the access to a large archive of art images was never granted. Shiode (2002a) continued to pursue the possibility of disseminating art and cultural contents online, which was finally granted by the Petrie Museum of Egyptian Archaeology, University College London, and the study on 3D applications was subsequently merged to a much larger initiative on constructing 3D models of Egyptian archaeological sites (Section 4.3).

4.1.6 Summary of Findings on the Virtual, Dynamic Art Gallery

This study discussed the use of cyberspace for providing a museum experience. A survey was carried out on the current state of virtual museums. They were classified into different types depending on the contents and the services provided. Several of these *museums* were in fact 3D or pseudo-3D virtual environments most of which gave a good sense of spatial context. However, they were dependent on certain languages and technologies such as VRML, 3D Java, QTVR or SVR. These techniques required special browsers or plug-ins to display the contents properly at the client's side. A prototype of a virtual museum was then proposed, featuring the dynamic rearrangement of its collection. If it were not for the unique spatial features of cyberspace, construction of such virtual museum would have been much more difficult.

As this case study is based on a prototype model, there are a number of issues left for future studies. First, a more sophisticated multimedia interface with extensive interactivity is needed to enrich the art experience. Information given in text form could be descriptive but less comprehensive when compared to those by sound and visual symbols. We will discuss this furthermore in Section 4.2, where Kanoshima and Shiode (1998) developed a multimedia interactive aesthetic environment for online art experiences.

Another issue is the design of the exhibition room. The prototype model automatically adjusts its room size to the amount of contents exhibited and is, therefore, incapable of generating the delicate room shape of the traditional museums. From the decorative viewpoint, a separate database may be necessary, where information on different types of interior details is saved for the creation of the best fitting gallery scene. The floor plans can be set with certain criteria such as minimum coverage area and generate the rooms accordingly.

Clearance of the legal issues concerning copyrights is the biggest challenge of all, as it will be the major constraint whenever exhibiting copyright protected art contents in public. There is hardly any feasible solution towards this discussion and, because of this, the case study only featured a limited number of Japanese print arts in low-quality resolution images, which conflicted with the initial aim of the study to provide better art experience.

Finally, integration of the multi-user environment is crucial for the effective use of the system. In order to avoid conflicts between the visitors, we may have to adopt a certain priority scheme. For instance, we can restrict the server to accept commands from only one user within certain timeframe. In this way, a visitor can exclusively rearrange and modify the gallery without being interfered by the other visitors while others may still visit the scene and explore the contents (See for instance, the Digital Museum Project lead by Sakamoto (2001) at Tokyo University Museum in which online users were allowed to interact with the environment).

4.2 Interactive Exhibition for the Aesthetic Experience in Cyberspace

4.2.1 Using Cyberspace as a Medium for Aesthetic Experience and Learning

This section discusses the intelligent use of information space that helps its visitors to construct the aesthetic approach to art experience. Here, aesthetic approach is defined as a process of engagement to and learning about the work of art involving one's perceptual, cognitive and sensual awareness towards the visual image. Using hypertext contents and user interface, a proto-type system is designed to provide learners with a navigation system that supports their creative and aesthetic approach to their visual experience. This navigation system may forge 'visual thinking' and offer the opportunity to actively learn through which human creativity and sense can function towards aesthetic experience. The process of learning is also clearly distinguishable from accepting rigid facts or pre-determined interpretation of the painting and adds value to the virtual experience of artefacts in cyberspace.

Museum activities online

Development of Internet services has provided museums with the effective means of making their resources widely available to the public. Their virtual galleries and exhibitions offer online visitors with digital image of museum collections and assorted information via computer network. However, most of the educational activities of the so-called "virtual museum" tend to focus on publishing images and disseminating information on their collection, rather than providing a truly new form of exhibition (Sweeney 1997). Hermann (1998) argues that the more the digital system capabilities develop, the more museums will begin to use them for more than a simple data-processing task.

Cyberspace has the potential to create a dynamic and interactive learning environment that museums can utilise for serving their pedagogical purpose more effectively. However, we would first need to identify the ways museums can use this digital communication system to stir virtual visitor's interest and, thereby, to deepen a personal and aesthetic experience and to promote the desire for further learning about the museum collection.

Virtual environment for learning about artefacts of museum collections

The recent increase in online, digital museum programs have resulted in a paradigmatic shift on how we view the museums and interpret their objects, especially when offered in a virtual environment. The fundamental role of the museum is to promote and inspire human understanding of cultural objects by providing the relevant information that accompanies them. Kenderdine (1996) indicates that the crucial element of an online exhibition is not the fabric or the texture of the original object but the information associated with the artefacts, because it is the information that integrates virtual objects and virtual visitors.

Within information spaces, the amount of information and the degree of interactivity of the programme support are the two essential factors of visitor's communication with the object. Therefore, the museum's implementation of an interactive communication system to the presentation of traditional material is in itself a challenge towards the educational programme in the virtual museum settings.

4.2.2 Museum Education and Learning Theory

Constructivist learning theory

Hein (1998) observed that learning within the context of museum is a *sense-making* activity rather than a process of information gathering. This sense-making is seen as a process in which a visitor will assimilate new information into his or her personal context to reconstruct new meanings and understandings in individual context. This is called *constructivist learning theory*. According to this concept, learning is not the understanding of the *true* nature of things, or the accumulating of perceived ideas into a memory system in the brain. It is a personally and socially driven construction of understanding produced as the individuals interact with the world. Constructivist theory view a museum as a place in which people choose what they want to learn and construct their own understanding through active exploration and experience with real objects as well as the use of various interpretative panels or other supporting media.

The concept of utilising multimedia technology as learning aid involves interactive features such as user-driven image retrieval and information manipulation. This allows visitors to select information and use it for structuring creative pathways to construct their own understanding. The use of an interactive communication system would offer a powerful solution to the constructivist learning. In other words, a visitor-driven information manipulation can be regarded as the resource of information for individual exploration of understanding the art object. These systems provide a virtual environment where information is no longer regulated by the organisational methods of the pre-determined, sequential arrangements used in traditional exhibition communication. Instead, they allow non-liner, random access to information and enable the visitors to explore their databases in ways similar to our intuitive thinking through the creation of personally determined links (Fahy 1996). The ability of cyberspace to emulate and stimulate human thinking can be thus regarded as an effective medium for supporting constructivist learning.

Aesthetic education in art museums

Conventional art museum and galleries tend to present works of art within a framework of an academic discipline ordered by recognised communities of scholars and established conceptual structures. This art-history approach leads to the situation where the value and the meaning of an art object is given by the institutional ideas of these art museums — the audience would be forced to act as a passive recipient of their ideas. This conventional structure is still reflected in some of the *virtual exhibition* shown on the websites of several art museums. Our experience of learning can be achieved only through the curatorial wisdom of art museums, leaving little room for visitors' individual interpretation or creative thought on the part of the audience.

Recent trend in the philosophy of art education in museums is that educators should look towards learning theory to help in designing educational programmes in order to widen the possibility of the visitor's rich experience with museum collections. Constructivist learning theory becomes an important paradigm for the educational strategy of art museums. This is due to the fact that many art educators have started to feel that learning in art museums consists not only of learning facts about the art object, but also of appreciation of art based on subjective reaction towards the aesthetic quality of art object (Weltzl-Fairchild 1995). Visitors may also have some emotional reactions to the expressiveness of paintings derived from the surface texture or the tone of the original colour of pigment. Viewing art is not only a receptive process; it is a creative process of looking that evokes emotions, stimulates the imagination, and provokes criticism and other psychological activities. An implicit idea about aesthetic experience shared by many art educational theorists (Brown 1989, Csikszentmihalyi and Robinson 1990, Housen 1992, Feagin and Subler 1993, Walsh-piper 1994, Xanthoudaki 1997) is that *aesthetic experience* refers to an active engagement to visual phenomena through perception, cognition, and emotions in individual reaction towards an art object. Csikzentmihalyi and Robinson (1990) claim that, by facilitating the aesthetic experience, art museums can transform their environment from a mere distribution agency of art object information for a passive audience to a laboratory which can foster an individual and intelligent encounter with art objects.

4.2.3 Online Aesthetic Education Programme

Based on the above discussion, we will now propose an online system for a visual experience where visitors can play an active role to explore their own ways of shaping the aesthetic experience. The design concept is based on the following factors.

Personal encounter with works of art

Aesthetic experience is a process of constructing personal understanding about the art object. Individuals respond and behave in very different ways when they confront works of art, and thus, the multiplicity of approaches to a single art work may be indeed overwhelming. For example, some people prefer to take an art historical approach while other people may approach the work of art in terms of its visual expression. Yet for some others, the subject matter in the work of art could be the crucial focal point of aesthetic contemplation. It is crucial that the program meets the demand for diverse approaches to art experience so as to enable learning in individual context.

Creative encounter with works of art

Aesthetic experience is created through the interaction between viewers and objects. According to aesthetic educationalists, there are three faculties of human nature employed in communicating and coming terms with art objects: perceptual skill; intellectual skill; and the skill of sensitive awareness. By encouraging the viewer to activate their looking, and thinking and feeling towards art object in their visual experience results in an active engagement with art objects.

Three human skills in visual experience

The aesthetic education should support viewer to activate human intelligence in the following areas.

(a) Perceptual skill: the ability to respond to various types of visual stimuli and to focus one's attention to the art object. Perceptual skill can be educated through the provision of the analysis of the formal qualities of works of such as composition, space, colour, line, tone, texture, medium, technique, and subject matter.

(b) Intellect skill: the ability to understand the relevance of general knowledge about works of art. Intellectual skill can be developed through the provision of diverse information about the work of art such as concept of style, the artist's biography, the historical, political aspects of an art object, and information about religion, iconography, and symbolism.

(c) The skill of sensitive awareness: aesthetic sensitivity which arouses emotional responses in the mind of the viewer during his or her visual experience. The emotional impact can be enhanced through the provision of various media for learning.

An interactive exhibition built within cyberspace can provide a user-driven learning experience that allows visitors to have random access to varied information related to their interest. Assuming that the content of the program is designed to support visitors to construct their own creative pathways through assorted information about an art object, it can offer an effective means for aesthetic education. In addition, multimedia presentation offers an experience shaped through browsing a variety of digital information in text, image, and sound; and thus encourages the visitors to use their cognitive, aesthetic, and emotional abilities much more than the traditional presentation on the museum floor would.

4.2.4 *Methodology for the Aesthetic Approach Online*

<u>System Framework and User Interface</u>

We adhered to the standard framework of HTTP server/client system for various reasons. Some of the existing virtual museums employ the technologies of VRML, Superscape or QTVR to attain a 3D or psuedo-3D environment. However, the actual effect of such virtual 3D museum towards the aesthetic experience of the visitors remains controversial at this stage. Besides, our objective is, rather than to reproduce the space of conventional museum in cyberspace, to utilise cyberspace for practising aesthetic experience in such way that could not be attained in the real space. Lastly, we assumed the usage on a home PC with a fairly modest processing ability and a normal phone line connection. The system consists of two elements. One is a collection of multimedia data that includes texts, sounds and visual images. The other is the network of links between these data that enables visitors to interactively navigate the information space and explore their personal aesthetic experience

Table 4.2.1 The environment that supports the construction of aesthetic, visual experience (Source: Kanoshima and Shiode 1998).

Dimensions of Aesthetic Experience	*Definition*	*Activities in Cyberspace*
Personal encounter with works of art	A personal construction of understanding about the art object.	Allow visitors to choose their own entry points into the exploration of their visual experience (freedom of navigation).
Creative encounter with works of art	An involvement with the learning process involving looking, thinking and feeling.	Assist visitors build their own creative pathway of learning experience using perceptual, cognitive, and sensitive domains.
Development of confidence in subjective reaction towards art objects	Enlargement of one's individual consciousness about the work of art due to the individual pathways of experiencing art objects.	Provide visitors with the record of their activity and the real-time track of their path (feedback).

Table 4.2.2 The three human skills for the visual experience and the development of these skills (Source: Kanoshima and Shiode 1998).

Human Skills in Visual Experience	*Activities for the Development of Skills*	*Devices in Cyberspace*	*Effects*
Perceptual Skill: The ability to respond to various types of visual stimuli.	1.Provide the opportunity to analyse pictorial elements of the visual image. 2. Offer viewers many different entry points to the pictorial qualities of art works: a. composition b. space c. colour and line d. technique e. medium f. subject matter.	1. The provision of the tool for art observation that enables free focusing and referencing across the hot spots of the image with cursor placement. 2. Retrieval of detailed information of parts or whole visual image for closer observation using zooming function. 3. Information partition whenever and wherever the spot the viewer wish to receive the visual and auditory information.	1. Effective in refining the audience's visual acuity and in sustaining viewer's interest in visual elements. 2. Effective in making the insights into the relationship between an artist's technique materials and expression. 3. Effective in providing the opportunity to make close observation of works of art according to their own interests.
Intellectual Skill: The skill of understanding the relevance of general knowledge about works of art	The provision of diverse information about the work of art including: a. concept of style b. historical and cultural aspects of art c. biography of the artist d. religion, iconography, symbolism.	The provision of intuitively comprehensive user interface device for multiple cross-reference search	Knowledge about an art object allows viewers to look at it from the stand-point of its role, its function, its cultural values in the society and also, to understand about art objects in a broader creative context.
Sensitive Awareness: Aesthetic sensitivity which arouses emotional responses during the visual experience	The provision of various media for learning.	A parallel retrieval of visual and sensual information.	Sensory-exciting experience may allow visitors to use their emotional faculties in the process of learning.

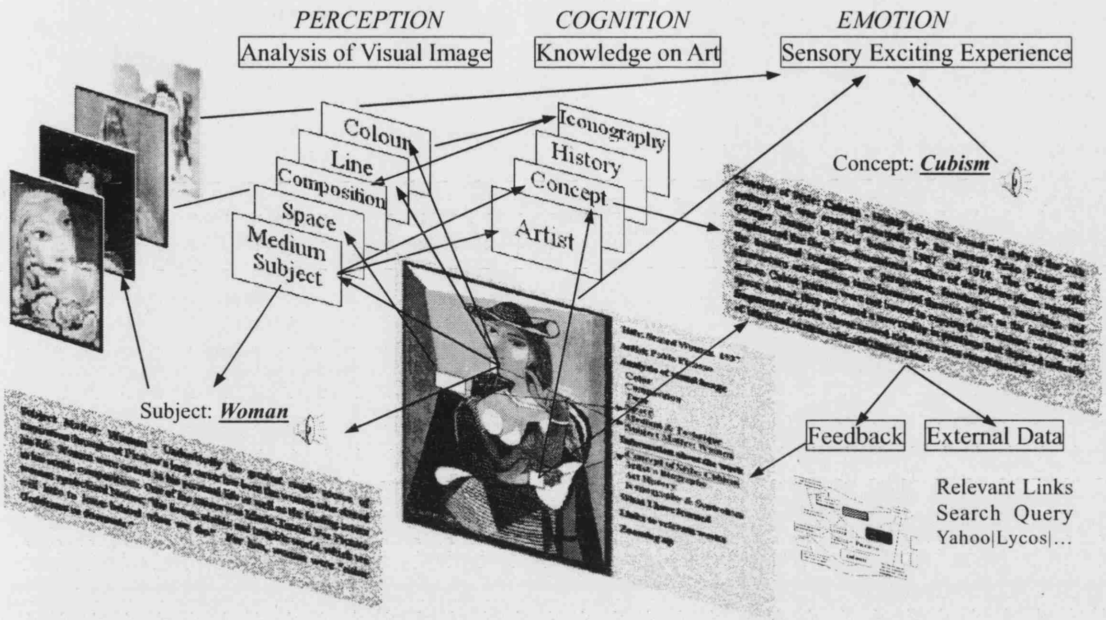


Figure 4.2.1 An example of image exploration procedure (Kanoshima and Shiode 1998).

within cyberspace. The links form a semi-lattice structure so that the visitor can navigate according to his or her own interest; rather than being forced to follow a pre-set path, which has been the case in many of the conventional museums as well as in some of the so-called 'virtual museums.' In order to enhance the virtual aesthetic experience to a full extent, the system provides various kinds of information that stimulates the visitor to use three human faculties when he or she has visual experience; i.e., perception, cognition and emotion.

A conceptual image of art exploration procedure is shown in Figure 4.2.1. Each piece of information is retrieved from the database stored on the server and displayed on the client side. In essence, the visitor will repeatedly go through the following processes.

1. Select a starting point by searching the artist, art work, period or theme.
2. Place the cursor on the picture and click on the spot of particular interest.
3. Select the option, medium or the issue of interest from the menu.
4. Explore the information
   (a) Receive the documented information
   (b) Listen to the audio assistance
   (c) View a relevant art work
   (d) Explore external links provided by search query.

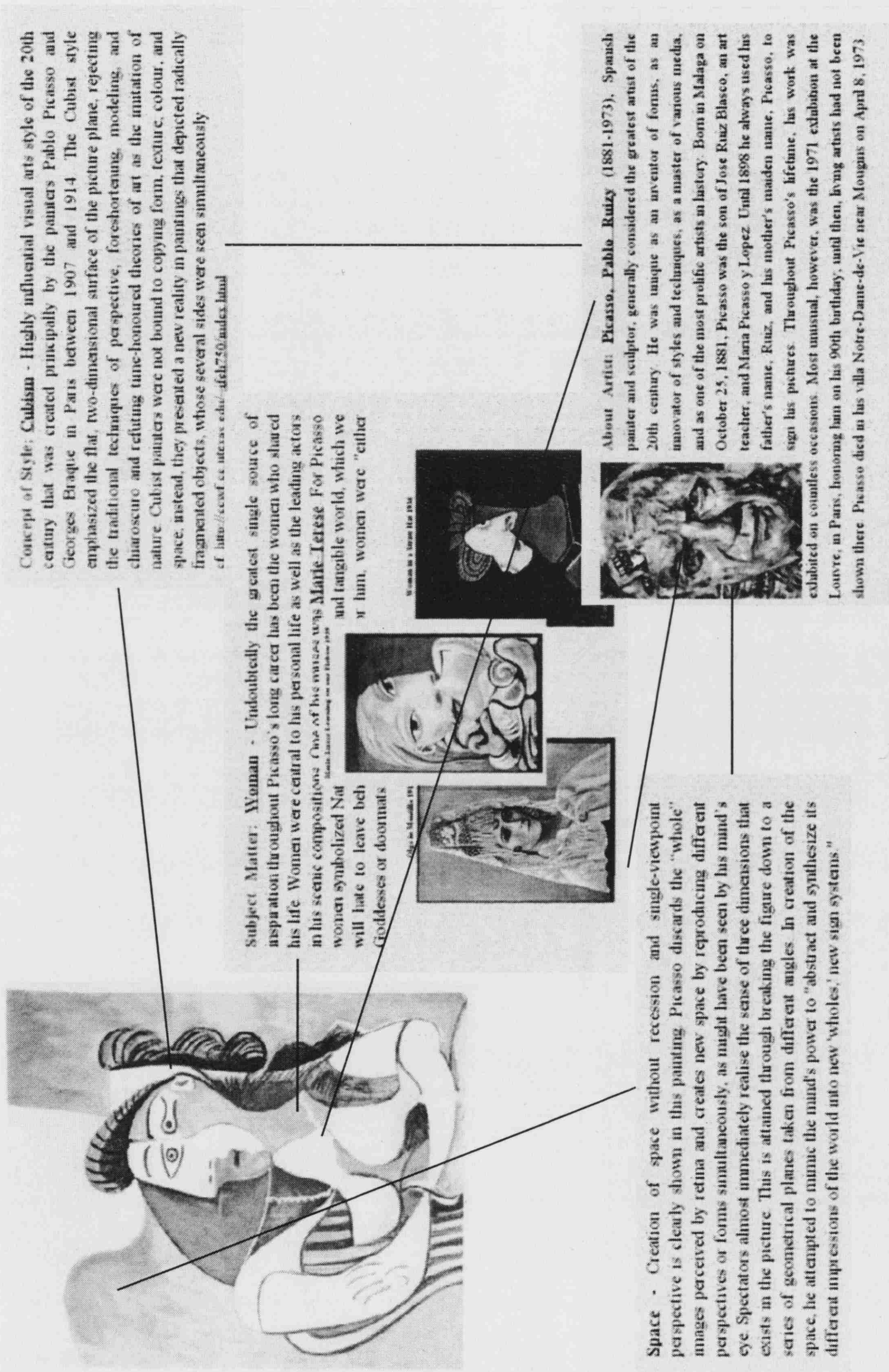


Figure 4.2.2 A snapshot of the image exploration system constructed in this study.

Types of Information Visitors Receive

Based on the above architecture, the system provides the following data and information.

1. Perception (analysis of visual image): Colour, line, composition, space, subject matter relevant to each spot of the art work.
2. Cognition (knowledge on art): backgrounds on artist, concept, history and iconography.
3. Emotion (sensory exciting experience): full exploration of the art work using zooming function; visual such as relevant works by the same artist, and explanations given on voice guide.

The first type of data is obtained by placing the cursor on each spot. Whenever a term or an artist's name is focused, the system sends a search query to multiple search engines and automatically lists up the links to the relevant information located outside the system.

The visitors will also receive their performance feedback. In fact, every movement of the visitor is recorded on the server as a log file and the trace is given on real-time basis. This enables the visitor to refer to the locus and observe the path he or she has come through.

4.2.5 Summary of Findings for the Online Aesthetic Experience Study

This study proposed an interactive navigation system that supported aesthetic approach to visual experience in cyberspace. The optimal use of interactive communication systems enables an active participation from the users' side, where the visitors are encouraged to pursue and direct their intellectual curiosity at will. This user-driven learning environment is important for the museum's online educational project, as their websites are targeted towards potential audiences from a wide range of ages, interests, and learning styles. A preliminary study on this aesthetic learning system suggests that the effective use of cyberspace can open museum's online educational opportunity, provide more enjoyable and enriching experiences, and add special value to the use of the Internet service in the museum context (Kanoshima and Shiode 1998). We will discuss this aspect in further details in Section 4.3, which focuses on offering an online teaching and learning resource on arts and cultural theme with an aid of 3D and multimedia contents.

4.3 Digital Archaeology: Virtual Reconstructions of Egyptian Built Environment on the World Wide Web

The previous two sections discussed the prospect of utilising information space for enriching our art and cultural experiences. This section will further investigate the potential to utilise information space for such purpose. The effectiveness of the 3D VR models and online teaching and learning resources will be discussed by way of examining some of the models created by the author within a three-year project (Section 4.3.4) (Grajetzki and Shiode 2003, Shiode 2005). In particular, we will produce an archive of online teaching and learning resource on archaeology contents with a focus on the extensive collection of Egyptian artefacts and excavation records preserved at the Petrie Museum of Egyptian Archaeology, University College London. The contents developed in this study are publicly available and are in fact being used in several courses and lectures in the related discipline in a high-school or university setting. The usefulness of these contents is also evaluated by external peers and is discussed in Section 4.3.5.

4.3.1 *Use of 3D VR Model in the Context of Cultural Heritage*

One very effective way of delivering information resources on art and archaeological contents is to create an online teaching and learning site that features images of artefacts, maps, illustrations, narratives, 3D visualisation utilities, and other forms of teaching materials. This section explores the media of virtual encounters as vehicles for learning about the cultural, social, technological and various other aspects of the past, using an online resource that is usable by a wide audience. Reproducing a destroyed historic landscape using excavation records and surviving artefacts provides us with the opportunity to visualise, explore and present ancient sites in their probable forms. Furthermore, it will allow us to compare them in a visible and, hence in the form that is intuitively recognised, with alternative scenarios that have been suggested in the past. In addition, the 3D VR models reproduced to life size allows the visitors to virtually immerse into and walk through the scene.

Applications that build on 3D VR models are increasingly popular in a variety of fields. For instance, several attempts have been made in the fields of art and archaeology, for virtual presentation and reproduction of historical or heritage sites (see, for instance, Forte and Siliotti 1997, for a collection of reconstruction cases). However, most projects are restricted to visualising an existing site or constructing a realistic model where the original plan is known. This section proposes a generic method for visualising the possible forms of historic sites whose precise forms are unknown and, therefore, have to be reconstructed to their probable form based on the best assumptions and from the few surviving artefacts as well as the excavation records from the site.

The 3D reconstructions featured in this section seek to incorporate the known archaeological and geographical data, including landscape and other contemporary edifices in its vicinity, the past and present colouring of individual buildings, and the likely phasing of settlement construction. They are aimed at providing their most likely appearance at a certain time as a way of encouraging the viewers to evaluate the evidence for themselves, for example through comparison of the different paths that might have been taken in reconstruction. This represents quite a radical departure from the idealised versions that have often hitherto been produced for other sites. In broader terms, it can be considered as consistent with a shift in archaeology from presentation of a single confirmatory representation that is based on one person's or group's interpretation of the evidence, to a more exploratory and participatory approach to sifting evidence and encouraging wider participation in the evaluation of scenarios.

This is a major breakthrough not only in the field of Egyptian archaeology but also for other archaeological and aesthetic applications. Many Egyptian sites have never previously been visualised using any form of 3D digital representation, let alone delivered with the options of walking through the models or comparing different interpretations side by side. The examples drawn in this section are all adopted from a three-year project, Digital Egypt for Universities (*http://www.digitalegypt.ucl.ac.uk/*), on which I have worked full-time between August 2000 and July 2003. We have been in a privileged position in that we were granted with ready access to a huge range of artefacts and the archaeological records of W.M. Flinders Petrie and other excavators of the late 19th and 20th Centuries[9]. These are

[9] W.M.F. Petrie (1853-1942), after whom the Museum is named, was one of the main figures in Egyptian archaeology, who excavated over several decades (about 1881-1938) on many sites in Egypt (and Palestine). His records and the material that he excavated are of central importance for reconstructing Egyptian culture. The Petrie Museum is a particularly important source of information concerning Egyptian prehistory. The Museum has many very significant finds from all of Petrie's

preserved at the Petrie Museum of Egyptian Archaeology, University College London, in one of the largest collections of its kind in the world, comprising some 80,000 objects covering that cover almost all periods of Egyptian history from the Palaeolithic to the Islamic Period. By summer 2002 a separate project had completed a photographic inventory of all of these objects, and, using these copyrighted images, we assembled an important resource for higher education, which provides background information on many of these artefacts. The connection with related sources such as excavation notebooks, tomb cards and the publications of the British Institute of Archaeology also proved to be valuable assets for the users.

The methods that are proposed for and applied to each reconstruction here are generic, and they potentially pertain to a vast range of historic environments. The contents are offered through a range of media including 3D VR models, audio files[10] and digital images of archaeological finds, as well as information provided under several different cultural categories or based on temporal and locational classification. A combination of Java and the VRML97 environment was adopted as a primary means to visualise texture and create 3D models so as to minimise the dependency on a particular platform or an operating system. This is complemented by other forms of online material such as movies and still images, to ensure access to the contents by users with slower connections and older computer environments, thus delivering them to a wider audience.

In terms of Egyptology, the contents offered in this study would be a useful resource for the archaeologists working in the 'field.' For instance, its typologies of pottery and everyday objects are essential for identifying the dates of the finds on archaeological sites, and, by offering an online resource, this knowledge can be served anywhere in the world through the Web. This is particularly useful, as Egyptological research often focuses on single aspects of material or written culture. Although one role of the project was to

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excavations including: Naqada, the key site of prehistoric Egypt, after which the whole period is called; Tarkhan, a cemetery with about 2000 tombs; Abydos, the site of the earliest royal tombs; and Hierakonpolis, the main cult centre of the period. The collection also includes several thousand objects from Guy Brunton's expeditions, including those to the Qau-Badari region. The objects from these historically pivotal sites provide an excellent background for recreating important aspects of ancient Egypt, and these sites are available for public access as 3D VR scenes (Shiode 2003).

[10] Audio fragments allow users to experience the Ancient Egyptian language, insofar as it is possible to reconstruct its sounds. This is very important for students, not only of Egyptology in particular, but also of archaeology and, more broadly still, in cultural studies. The ancient Egyptian language contained many sounds unknown in Europe; only audio can bring these to modern speakers of those languages.

concentrate on particular artefacts, the broader objective was and still remains as combining the knowledge of different research areas to provide a full picture of this important culture. In fact, any single object could be related to other objects and to the architectural context in which they were found, thus establishing a basis for comparison across space and time.

The rest of this section comprises three parts. First, it addresses the methodology and techniques we applied for developing the online learning and teaching resource. This is followed by a series of showcase examples each of which focusing on some of the individual sites that were reconstructed in the project. We conclude by summarising some of the insights obtained, and discuss some of the issues encountered whilst creating the online resource as well as those revealed during the evaluation surveys.

4.3.2 *Methodologies Used for Constructing the Online Resource*

Composition of an online learning resource

This project utilises a wide range of media to improve the online learning experience and to help understanding the contents better.

Generally speaking, some types of online multimedia resources can be more visible and conspicuous than the others; for instance, the 3D VR models of ancient monuments or the audio recordings of the ancient Egyptian language tend to attract more attention than some other documents. However, as the primary objective of this project was to produce a comprehensive online learning resource, the site also features a series of self-learning aids including informal learning courses at different levels, and reading lists for the relevant subjects accompanied with summaries and reviews.

Photographs of the relevant monuments and artefacts recorded in high resolution also provide a valuable resource for distant learning of the subject. It also frees us from the budgetary constraints of paper reproductions that often dictate the objects be shown only as line drawings. As with many other cultural and social disciplines, publication of artefact images in archaeology used to be offered predominantly by high resolution prints of black-and-white and colour plates, but print runs for research publications tend to be costly and also limited in the number. Even the most recent publications of excavations are still offered in conventional black-and-white pictures and line drawings, but this may be likely

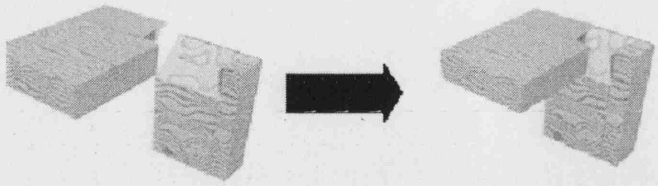


Figure 4.3.1. 3D models featuring ancient technologies: joints used in woodworking.

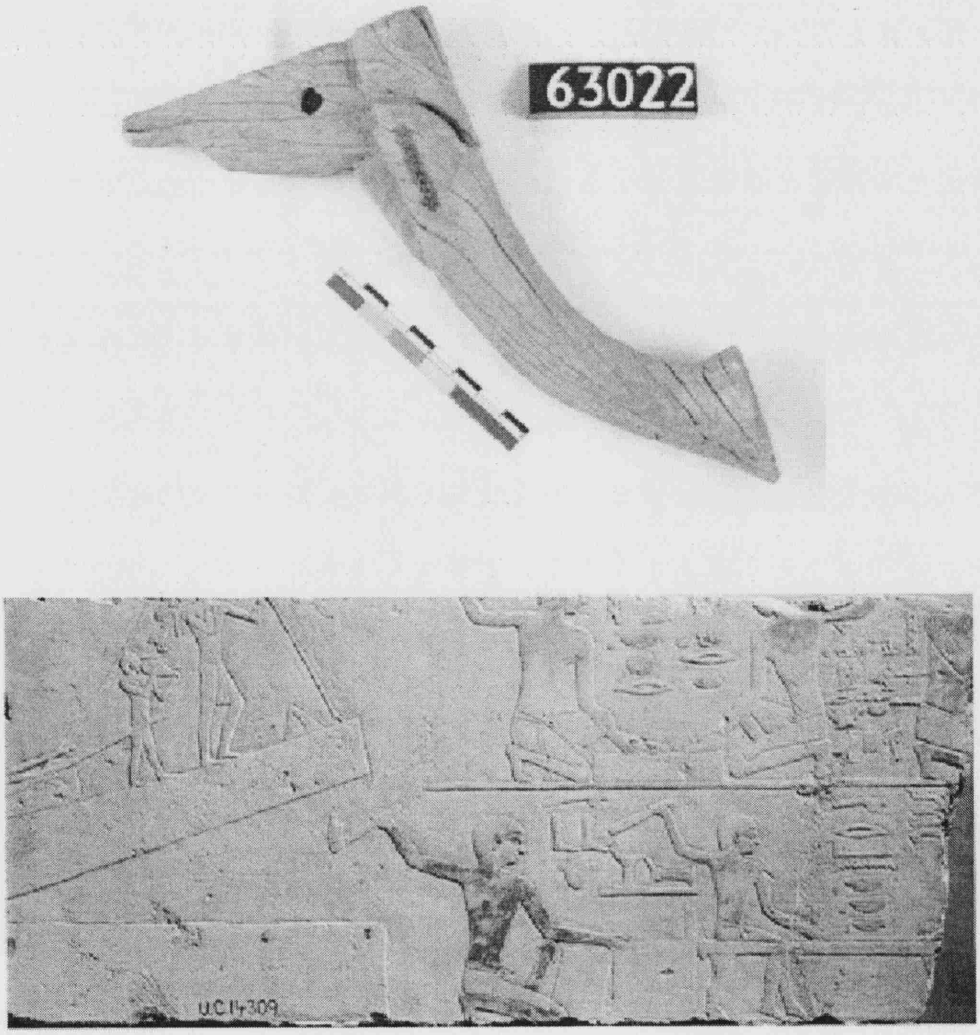


Figure 4.3.2. Pictures of objects from the Petrie Museum accompanying explanations of technology (top: wooden part of a woodworking tool called *adze*; bottom: tomb relief showing the use of a similar *adze*) (Grajetzki and Shiode 2003).

to change in the near future; once the convenience of the readily available digital images is recognised. The website also provides 3D illustrations and short movies to show the various technologies used in Ancient Egypt, and elsewhere in the ancient world (Figures 4.3.1 and 4.3.2). Charts and tables provide various data on the subjects covered and clickable maps reveal the locations of important sites in Egypt.

4.3.3 Reconstructing Monuments and Architecture in the VR Environment

Many of the archaeologically important places in Egypt have been either completely destroyed or are badly preserved, and this inevitably creates uncertainty in reconstructing historic forms. As such, the 3D VR models for each archaeological site offered in this study comprise several different possible representations in order to present the various forms suggested by different groups of archaeologists including the project team for this study.

While Egypt is well endowed with well-preserved temples and tombs, there are only a handful of well-preserved settlements. Paper reconstructions have always played a vital part in studying the architecture of the Egyptian and the Near East regions (Heinrich 1982). For instance, Badawy's (1954, 1966, 1968) history of Egyptian architecture exhibits an impressive number of reconstructions. The reconstructions by Emery (1991) of the Early Dynastic palace tombs at Saqqara (about 3000 BC) are also known as an important source, as are the two earlier versions of the reconstruction of the Sun Temple of King Userkaf (c. 2500 BC: Ricke 1965). The latter is an unusual example in that two different possible reconstructions of one temple are provided, in recognition of the uncertainty arising from the degree of destruction of this temple structure. However, with the exception of Ricke (1965), most reconstructions are offered as a single most probable form of the site and thus failing to address the issue of the ambiguity that arises from the poor conservation.

This problem becomes particularly pertinent when constructing an online resource that focuses on Petrie's excavation work, as many of the sites he excavated had been severely damaged (e.g. the Min temple at Koptos or the 'labyrinth' at Hawara). In some cases, it is difficult to estimate the shape and the scale of the monument, not to mention the original appearance of such places in ancient times. While more remains have survived at other sites, Petrie himself never tried to envision the design of the original buildings, and this task has thus remained uncompleted to this date. One example is the governors' tombs at Qaw el-Kebir, where Petrie (1930) only published the plans of the structures that he found during his expedition, and the plans and a full 3D drawing were provided later by another archaeologist who also worked at the site (Steckeweh 1936). Figure 4.3.3 shows a 3D model reconstructed in this study after Steckeweh's drawings (1936).

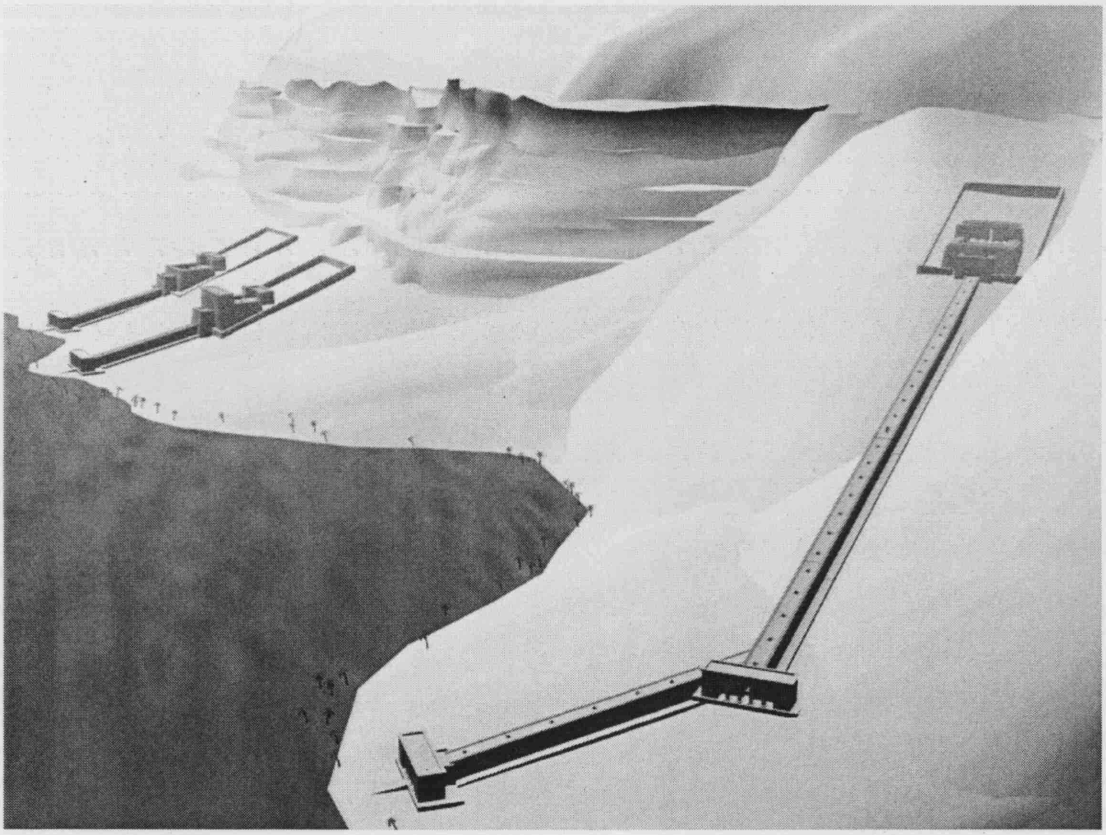


Figure 4.3.3. Reconstruction of the tombs of the governors at Qau el-Kebir (constructed by Narushige Shiode for the Digital Egypt for Universities project).

As the Steckeweh's reconstruction has been reproduced in many other publications, it gives us an impression that we know the original appearance of the buildings in detail. Yet a closer inspection of the reconstructions and the surviving remains raises many questions. For instance, we do not know if the causeways were really covered with a roof. Also, the size and the shape of the temple-like buildings by the river are not known. Finally, whether or not these tombs were actually ever finished remains a mystery. These issues can be addressed by the use of a flexible 3D VR model, where different scenarios can be studied by comparing their 3D representations and deciding on the most probable form.

The Digital Egypt for Universities project covered several reconstructions for each of the sites excavated by Petrie and others. Some of these versions are published on the Web for public access, with the intention of showing the unknowns rather than what is already known, and to visualise the possible alternatives. These models can easily accommodate changes in the light of new research findings and to disseminate them to many interested parties.

4.3.4 Relevant Studies on Online Egyptology

This study was unique in many respects. For instance, there has hitherto been no pedagogic Website in the field of Egyptology or archaeology. Also, despite the increase in the number of 3D reconstructions for single buildings or one particular site, few of them cover a wide range of sites and periods. In addition to this, many of the existing models are maintained by private individuals rather than research institutions. Some models are created by those who are not trained in this field and they often do not have access to the relevant research publications. Their representations frequently suggest a lack of deeper knowledge about the wider ancient landscape and architectural settings. For instance, several non-contemporary building phases co-exist in some models; and the colouring of buildings – a very important consideration with respect to visual impact – is often neglected. Also, many 3D reconstructions have been published in monographs of a general interest nature in recent years; but a publicly available model maintained on the Web is still rare. It appears that many archaeological institutions, universities and museums alike, remain unaware of the full potential of the Web resource, especially with respect to the combination of 3D VR models and the related narrative.

In fact, it transpires that there are only a handful of known Web-based research projects. Among them is the Berliner Wörterbuch (a major institution for collecting Egyptian vocabularies), which hosts the entire archive of 2.5 million digital pictures of handwritten slips, written at the beginning of the 20th century (*http://www.bbaw.de/index.html*). Also, the Griffith Institute in Oxford, UK is currently preparing an online archive on the excavation record for the tomb of Tutankhamen (*http://www.ashmol.ox.ac.uk/gri/4search.html*).

Similarly, the Museum of Fine Arts at Boston is composing a Web resource of their Reisner archives of manuscripts and photographs (*http://www.mfa.org/giza/pages/reisner.html*). Each of these projects delivers access to first-hand excavation records that have previously been inaccessible to the wider research communities, as they were stored in museums and archives which could be visited only with special permits.

Perhaps the most elaborate example of online resources on the virtual reconstruction of an ancient site is that of the Theban Mapping Project, an excavation mission at Luxor (ancient Thebes), which is housed in the American University in Cairo (http://www.kv5.com/). The Web site includes huge bibliographies as well as high-resolution pictures of the mission's finds, buildings inventories and historical notes. The Web site is focused on Thebes and the New Kingdom (ca. 1550~1070 BC) and can be adopted for teaching – although no on-line course materials are available. There are similar projects based on other excavations, such as the Tomb of Senneferi (http://www.newton.cam.ac.uk/egypt/tt99/index.html), and these initiatives are often connected with museums. They provide a general idea of the objects held in the museum and are thus useful for archaeological studies as well as the general school education. A summary of relevant Web sites is available at http://www.newton.cam.ac.uk/egypt/.

In sum, there is no comprehensive resource of Egyptian archaeology online, which makes this project unique. With the aid of the 3D models and other media, we offered information on a variety of social, cultural and technological issues as well as data from different time periods; and we also offered a series of course modules that can be used as teaching tools in classes.

4.3.5 Case Studies of 3D Archaeological Reconstruction

This section illustrates some of the 3D VR resource I produced between August 2000 and July 2001. Although 14 excavation sites have been reconstructed in the VR environment in total, we focus on three of them to illustrate the prospects and problems of using information space as a vehicle for online cultural learning experience.

Hemamieh

Hemamieh is a modern village that exists in Upper Egypt. In the early 20th century, several cemeteries and remains from habitats were excavated and surveyed at the edge of this settlement. The site is also known for the remains of a small village, which was excavated in 1924 by Caton-Thompson (Brunton and Caton-Thompson 1928: 69-116). This small village is believed to date back to around 4000-3500 BC in the Badarian period, which was the first Chalcolithic (Copper-Stone Age) culture in this part of Egypt. The initial goal of the expedition was not to produce a plan of a Badarian village but to gain insights on the connection of the Badarian culture to the Naqada culture, which was another prehistoric culture in Upper Egypt whose chronological relation to the Badarian had been previously unknown. The result of the excavations revealed that the Badarian level was located under the levels of the Naqada period, thus suggesting Naqada to be later. However, there has been little discussion on the nature of the excavated village until the growing interest in the prehistory of Ancient Egypt in recent years brought back the focus to the village. There are several unanswered questions regarding the excavated structures. To begin with, most of the structures are in-ground, round holes of about one metre in diameter. Figure 4.3.4 illustrates the process of constructing a 3D VR model of the Badarian village in Hemamieh based on Petrie's excavation record. The cylindrical structures from the Badarian period are extruded to the suggested height of 1.2 metres and are illustrated in grey shade, which are overlaid with the cemeteries from the Naqada period (as indicated by the green boxes). One theory proposes that these cylinders were used as storage containers for grain. However, some of them had been found filled with animal droppings, implying that they may have been used as stables, at least for some periods. One of the 3D reconstruction models show the use of these structures as stables (Figure 4.3.5).

Even the reconstruction of a relatively simple site such as this small village raises several issues. For instance, the height of these cylindrical structures, their roof structure, and the colour of the walls are all unknown. Also, the contour lines used for reproducing the landscape were estimated from the excavation record; and the level of the ground may have been quite different in those days. What we see in Figure 4.3.5, then, is just one of the many possible reconstructions despite its realistic appearance.

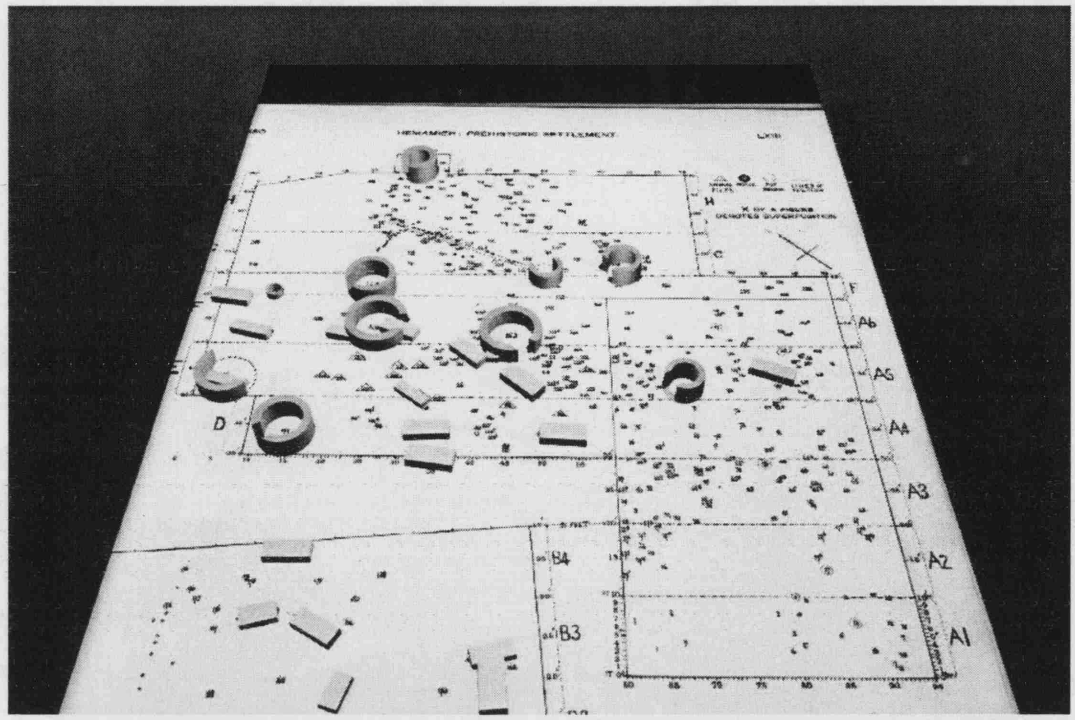


Figure 4.3.4. The process of constructing a 3D model of Hemamieh based on the excavation record by Petrie (constructed by Narushige Shiode).

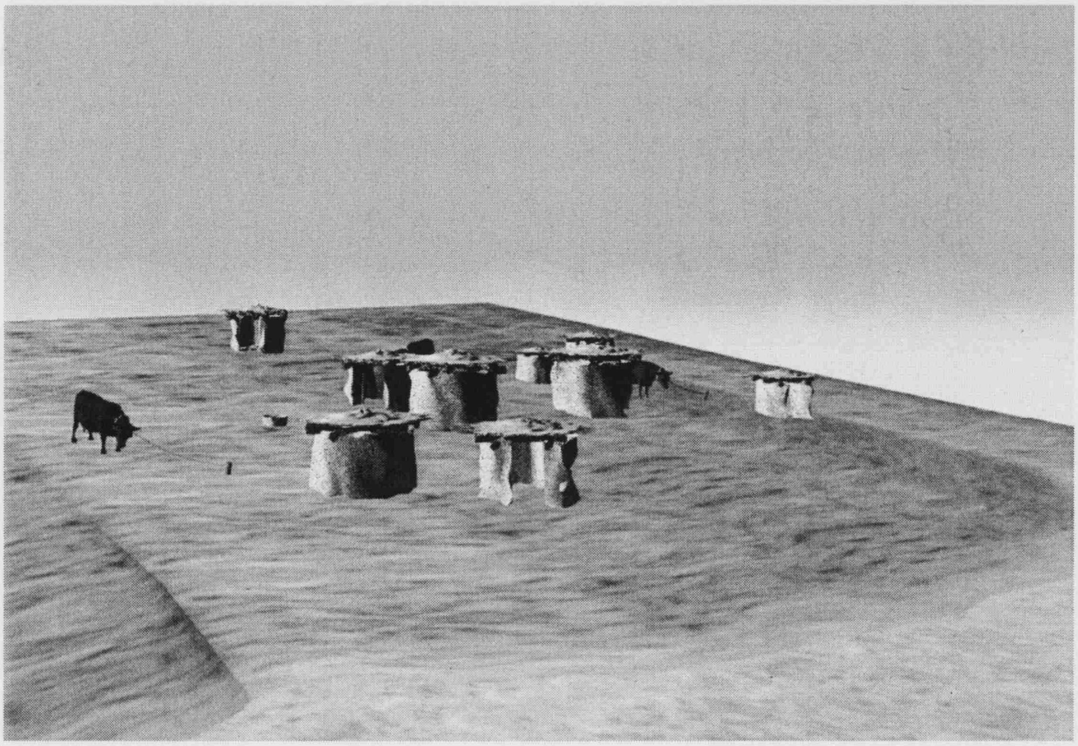


Figure 4.3.5. Reconstruction of a small Badarian village excavated near Hemamieh (constructed by Narushige Shiode).

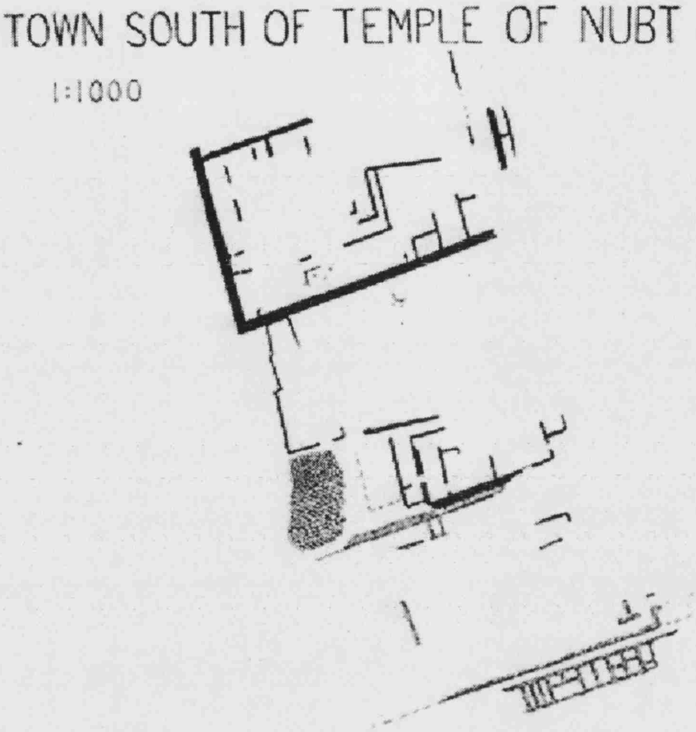


Figure 4.3.6. The published plan of the settlement structures found at Naqada (Petrie and Quibell 1896: pl. LXXXV).

Naqada

Naqada was first excavated in 1895 by Petrie (Petrie and Quibell 1896). The site actually consists of a series of settlements and cemeteries at the edge of the desert, about 24 km north of Luxor. The whole site is of special interest as this was the first case of excavation of tombs that date back to pre-Dynasty era (before 3000 BC). Today, Naqada is known as one of the major sites in Egypt from about 4000-3000 BC. Petrie concentrated his research on excavating the 2000 tombs, but also recorded and excavated structures at the site of the settlement.

The recorded structures (Figure 4.3.6) are large in scale and there is some debate about how these remains should be interpreted. In this study, they are reconstructed as three palace-like residential structures surrounded by a huge town (Figure 4.3.7). The importance of some of the items buried in the tombs at Naqada suggests that Naqada may have been the capital of an early kingdom. One possible interpretation of the remains of the buildings is that the heavily-walled structure in the North may have been a walled residential area with several buildings inside (that is, some kind of acropolis or fortress) (Figure 4.3.8).

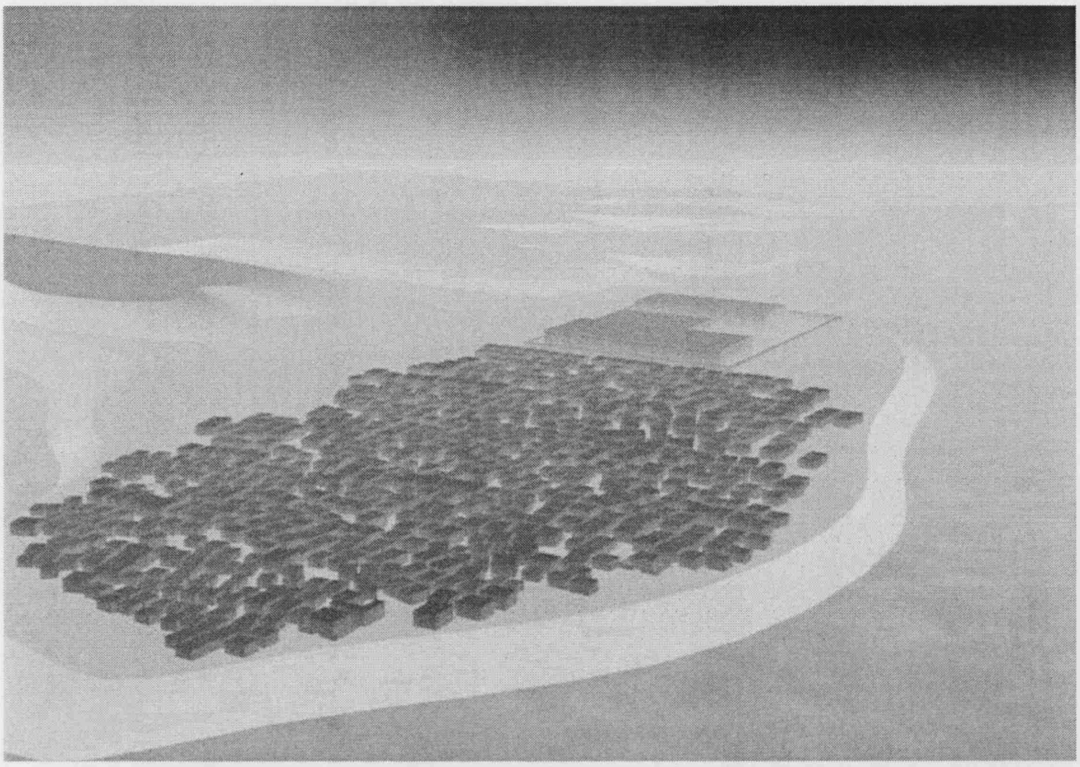


Figure 4.3.7. Reconstruction of the South Town of Naqada (constructed by Narushige Shiode for the Digital Egypt for Universities project).

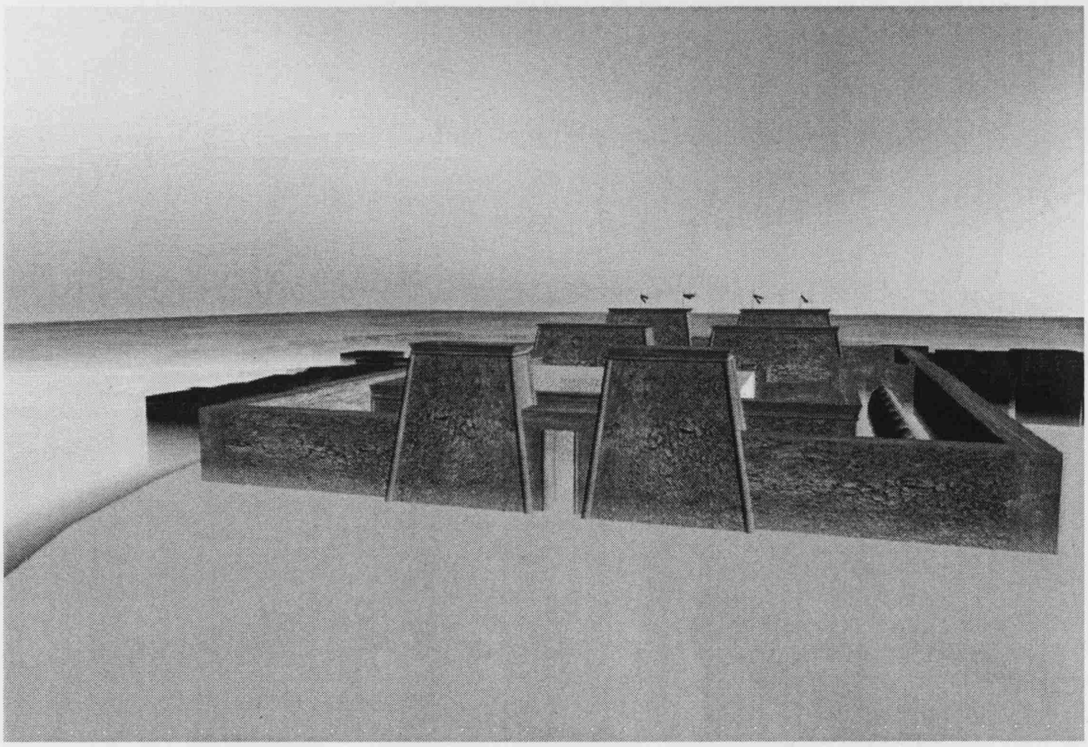


Figure 4.3.8. Reconstruction of the Temple of Seth in Naqada (constructed by Narushige Shiode for the Digital Egypt for Universities project).

Despite all the uncertainties concerning the exact size and the shape of this early settlement, the 3D VR reconstructions clearly demonstrate that towns had been already developed in the fourth millennium BC Egypt, in a similar way to those traced to the same time period in Mesopotamia. A video clip that features the transition of this area was produced to show the changes in the built environment over time. It helps users to visually appreciate the construction of the palace, the town and the temple in the chronological order and the relative time span between each development.

Figure 4.3.9 compares the size of some of the Egyptian and Mesopotamian towns side by side, demonstrating the larger scale of town developments in the Near East in comparison with the Egyptian settlements.

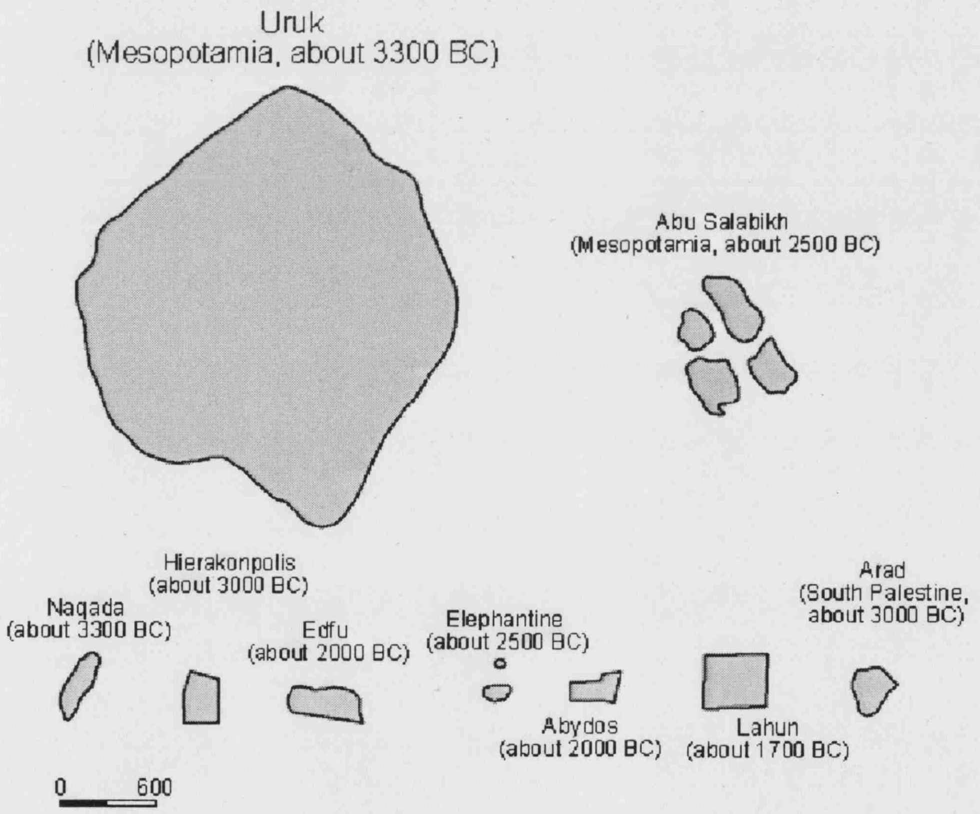


Figure 4.3.9. Size of towns and settlements in Egypt and the Near East (3300~1750 BC). (Grajetzki and Shiode 2003).

Koptos

Koptos is the site of an important temple, excavated by Petrie in 1893~1894. The main temple of the fertility god, Min, had been largely destroyed prior to Petrie's excavations, as its limestone walls were perfect for burning material. Unlike in other temple sites in southern Egypt, where many temples are built with sandstone rather than limestone, Petrie was not even able to draw or reconstruct a detailed plan of the most recent Roman construction, not to mention the reconstruction of the earlier temple buildings at Koptos. Only a handful of stone blocks with decorations were found with no clear reference to their original architectural setting (Figure 4.3.10). Other artefacts had been reused as part of the pavements of later temple buildings. Several fragments, including parts of three colossi statues dating to the time of state formation, demonstrate the importance of the temple in Pre- and Early Dynastic times (about 3000 BC).

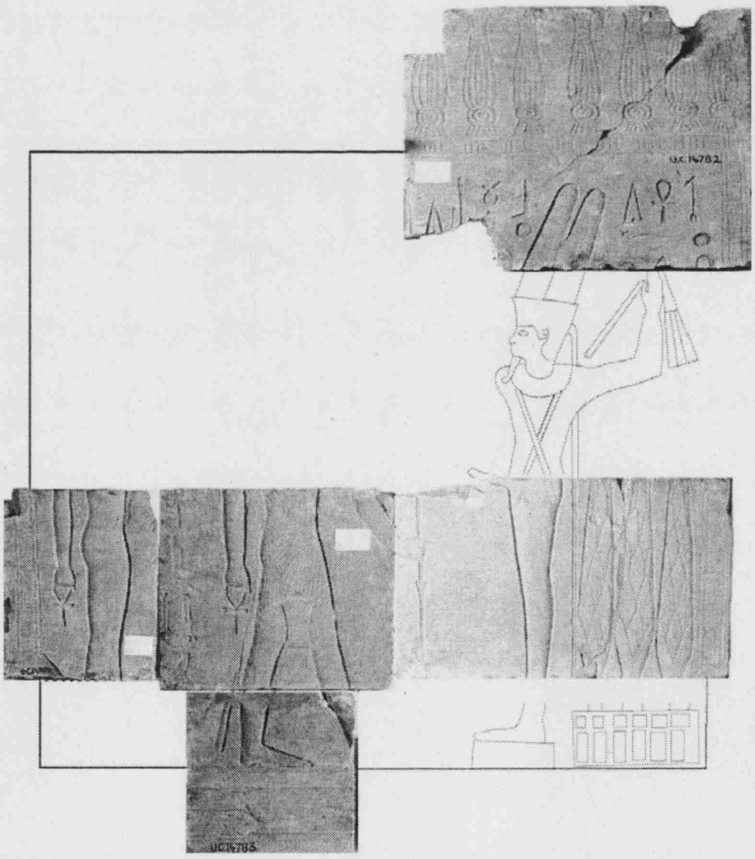


Figure 4.3.10. Reconstructed wall from the Second Intermediate Period temple of Koptos. The stone blocks are preserved at the Petrie Museum of Egyptian Archaeology. (Grajetzki and Shiode 2003).

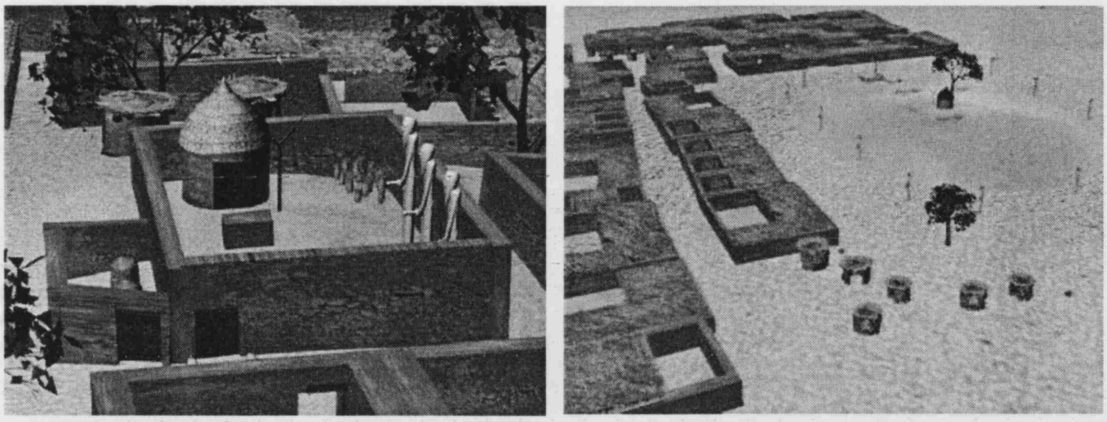
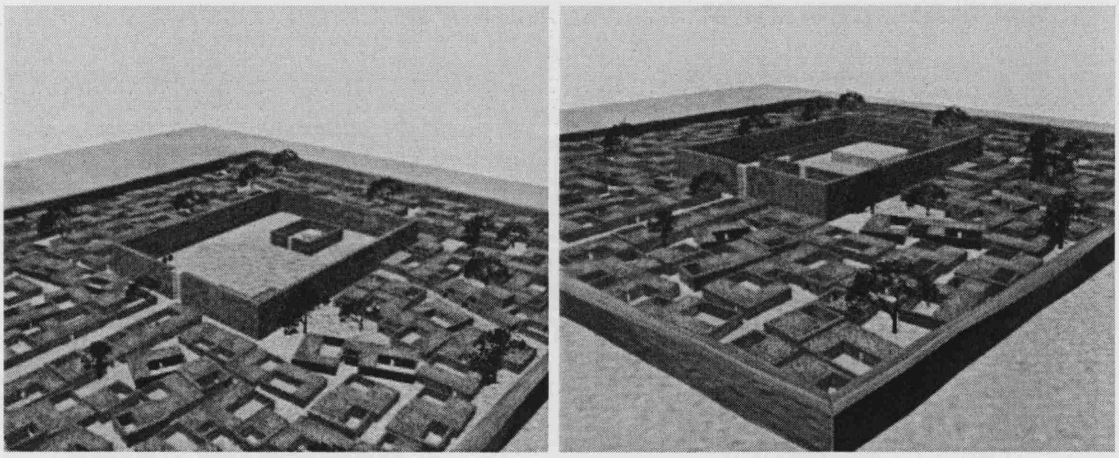
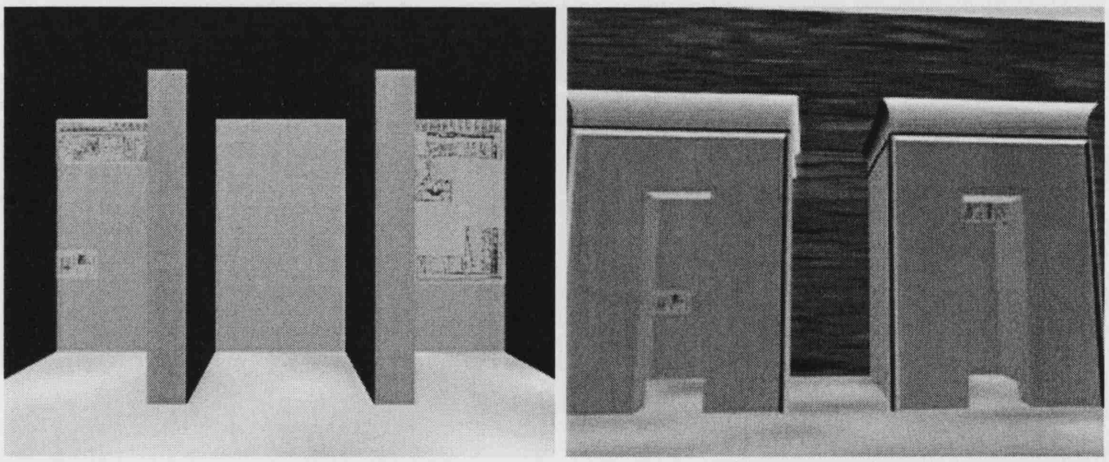


Figure4.3.11. Reconstruction of the Temple of Min in Koptos in the Pre-Dynasty and Early Dynasty Period (3000 BC) based on two different interpretations. (3D models and images produced by Narushige Shiode.)



(a) (b)



(c) (d)

Figure 4.3.12. Reconstruction of Koptos in the Second Intermediate Period (1650~1550 BC): (a) with the reliefs of king Intef Nubkheperra in the main sanctuary, (b) with the reliefs in separate chapels, (c) details of model(a) with the proposed arrangement of the reliefs in the main sanctuary, and (d) details of model(b) with the reliefs in separate chapels. (3D models and images produced by Narushige Shiode.)

In order to investigate different scenarios, a total of four reconstructions of the temple were produced. The first two are two different versions of the temple at the time of state formation (about 3000 BC) (Figure 4.3.11). They show the Temple of Min in the Pre-Dynasty and Early Dynasty Period, but with a slightly different setting in that the first model has an enclosed courtyard whereas the other version features an open space. These two contrasting model indicates the difficulty that we have in reproducing a site or a landscape with limited amount of evidence.

The latter set of reconstructions show the temples from the Second Intermediate Period (ca. 1650~1550 BC) (Figures 4.3.12(a)~(d)). They are of special interest because several stone blocks found at the temple site are now housed in the Petrie Museum. With some imagination and tiling procedure similar to a jigsaw puzzle, we can reconstruct several decorated walls (Figure 4.3.10), which would give a starting point for the 3D VR reconstructions.

Fortunately, there are several other sources and references available for the temple reconstructions of the Second Intermediate Period. These include similar temple buildings from the same period that are better preserved, and the stone blocks from the same site that are preserved in several different museums, which are believed to have come from at least six different walls and several doorways of two small chapels.

The two different reconstructions of the Second Intermediate Period temple provide a useful illustration and also serve as an example for the exploratory approach to 3D VR visualisation. Several reliefs found at Koptos by Petrie and by the French Egyptologist, Reinach, date from building activity in the reign of King Senusret I (ca. 1956~1910 BC). It appears that he added some reliefs to a temple that already existed at that time, and may perhaps even have rebuilt the whole temple complex during his reign, which makes the interpretation of the site as well as our reconstruction task all the more confusing and complicating. In the first version of the 3D VR reconstruction (Figures 4.3.12(a) and (c)), it is assumed that the main temple of the King had been ruined by the onset of the Second Intermediate Period, and that it was rebuilt under King Nubkheperra Intef. Assuming that the Middle Kingdom temple was destroyed during the Second Intermediate Period, the reliefs of King Nubkheperra Intef would seem to be part of the decoration of the principal sanctuary, and that they would have been entirely rebuilt under that King. The principal sanctuary most likely had three chapels standing next to each other: There is a central sanctuary with raised reliefs, and two other sanctuaries that are decorated with both sunken and raised reliefs. The existence of three sanctuaries in one temple was very common in this period.

In the second reconstruction model (Figures 4.3.12(b) and (d)), on the other hand, is based on the assumption that the main building of Senusret I was still standing in the Second Intermediate Period. The reliefs of King Nubkheperra Intef would then have come from two or three small chapels constructed outside of the pre-existing temple building as extensions. They would have been located inside an open courtyard surrounding the main temple building. The reconstruction of this version is supported by the discovery of a similar arrangement on the island of Elephantine that dates to the reign of King Wahankh Intef (ca. 2100 BC), where the King had built an additional chapel in the courtyard of the pre-existing Satet temple.

In terms of reconstructing the surrounding townscape, excavations have revealed that nothing had been preserved from the actual town of the Second Intermediate Period. The general impression of the reconstructions illustrated in Figures 4.3.12 is based on some other contemporaneous town sites that have been better preserved.

4.3.6 Evaluation of the Virtual Egyptology Contents

The three case studies illustrate the many issues regarding the reconstruction of a destroyed landscape with limited amount of evidence. In order to assess the level of awareness on the ambiguity of the models by the users and also to assure the quality of this online learning-and-teaching resource, different groups of external parties were brought in at the end of each project year. The credibility of the materials and the validity of the 3D VR models as part of an online learning resource were thus repeatedly tested and evaluated by external steering groups and users in the form of workshops as well as online surveys. The feedback was collected from the following three groups of people:

(a) a small number of Egyptologists from research institutions throughout Britain, who had first-hand knowledge of many of the site reconstructed,

(b) a group of environmental psychologists from University of York, who examined the validity of the contents as an online learning resource , and

(c) archaeology students and architecture students from the undergraduate level as well as the postgraduate level who tested the navigability of the website, accessibility to information, and the usefulness of the site.

Each participant of the workshops were given a brief explanation on the objective of the project and the nature of the contents, and were then asked to (1) follow a series of pre-selected links as well as (2) navigate through the contents and find the topics of their own interest; so as to measure the easiness of finding the contents, the adequacy of the length, the level and the type of information provided, as well as to identify any issues. The highlight of these workshops was a visit to CAVE (Computer Assisted Virtual Environment) at Department of Computer Science, University College London, in which these 3D models were displayed at life scale. The visitors could immerse themselves in to the virtual environment and "walk" through and "feel" the scenes.

The precise examination of the survey data from the workshops is beyond the scope of this thesis, and further details can be found in Quirke's (2003) report to JISC (the Joint Information Systems Committee), but the main findings were as follows:

(a) The contents of this online resource are of significant value for academic use in the field of Egyptology and archaeology. The site helps making the field of Egyptology more accessible and interesting to a wider audience. It would be extremely useful to have a similar resource for other major museums.

(b) Some of the materials were buried among the vast amount of contents and were thus difficult to find. It was suggested that several different paths and links should be provided to reach the same contents.

(c) The visual representation of the past provides a very valuable pedagogic introduction to Egyptology. In particular, the 3D models are extremely persuasive form of representation, which can in fact give the false impression that the representation is known to be accurate in its precise details.

(d) Visualising more than one option helped the users retain an objective perspective. It demonstrates that the distinction between a known fact and an intelligent speculation can be clearly made in a visual manner.

(e) It would have been more interesting if the users could interact with the 3D models in such way that they could change the colour, scale, shape, and design of the models they were in. (*A system that allows the users to interact with the virtual environment and other users will be discussed further in Section 5.2*).

In terms of the user interface, the surveys suggested that the structure of the project site should be kept as simple and user-friendly as possible, to enable an easier navigation. The ability to offer a range of contents sufficient to encourage repeat visits may have the opposite effect of making the site more complex and less intuitive. The only feasible remedy for this issue was to identify appropriate trade-offs, and also to provide as many alternative paths (including search functions) to each page as possible to increase the connectivity among the contents.

4.3.7 Summary of Findings on the Digital Egypt Project

This section highlighted some of the 3D VR models that have a strong presence both in terms of its visual effect and also for their significance in the archaeological discipline. It also illustrated the potential use of information space as a medium for visualising and providing information on ancient architectures and sites that have been long destroyed.

As part of the evaluation of the project, a list of 3D impact pages were created and were made directly accessible from each 3D model. These elicit user responses to the perceived impact of the 3D models, and seek to gauge the usefulness of the representations in relation to the user's research questions and requirements for that particular model.

Where appropriate, several models were provided for the same site, and they were compared with one another, as seen in Figures 4.3.12, 4.3.13, and 4.3.14. Nevertheless, many users still found any realistically-rendered 3D scenes persuasive and visually convincing, especially when walking inside these models with the aid of immersive virtual environment systems such as the CAVE.

Fourteen different excavation sites were reconstructed in 3D VR model in total, featuring many parts and many time periods of Egypt. The methodologies described are generic in the sense that they can be applied to the development of online contents for other archaeological sites. They can be also used in the creation of online teaching resources in other contexts. The combination of various media types such as 3D models, audio files,

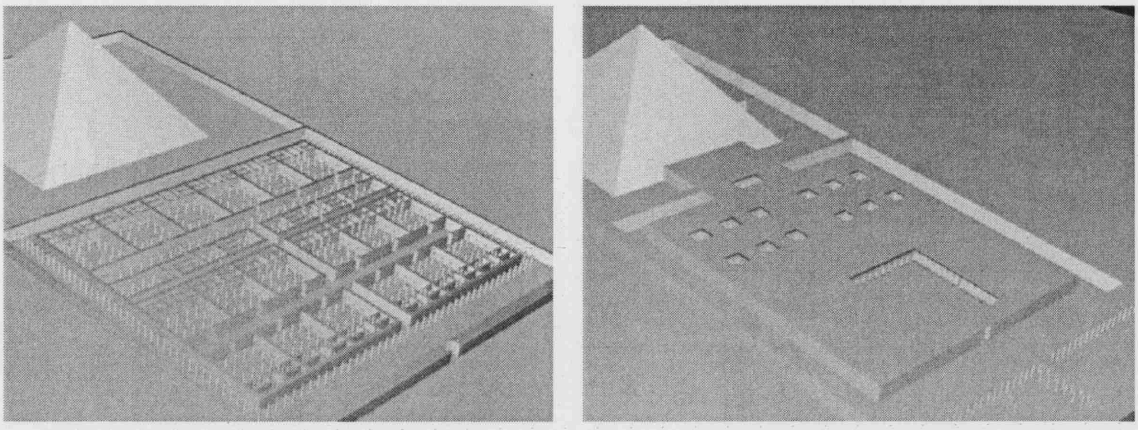


Figure 4.3.13 Virtual reconstructions of the great labyrinth and the pyramid complex of Hawara based on different proposals (constructed by Narushige Shiode).

excavation records and digital images of the artefacts offer a unique resource for students in Egyptology and archaeology but also in other areas. Furthermore, these resources reproduce historic landscapes at extents not developed previously, and in ways that are only possible through the use of information space. Many of the reconstructions offer new solutions for understanding buildings and some even offer a visual reconstruction of buildings for the first time. The reconstructions are supported by archaeological research conducted by the Egyptologists who have visited these sites, which also provides important background information on many sites.

As described in Section 4.3.5, external evaluation panels were brought in so as to gauge the usability, perceived validity and usefulness of the site at the interim stages. This has clearly highlighted the various issues and helped the project team to address the problems. For instance, while the 3D VR models are visually appealing and intuitively plausible, they can on occasions be overly persuasive where users regard them as a precise reconstruction based on sufficient evidence. In fact, most of the sites studied in the project have been largely destroyed and the representations offered are only one of many possible forms. Several sites are shown with different interpretations (as shown, for example, in Figures 4.3.12, 4.3.13 and 4.3.14) but the external evaluations suggested that their visual impact was still too strong and persuasive for some users. This was especially so when walking inside these models with the aid of immersive virtual environment systems such as the CAVE. There is no immediate solution to this problem, but if we could offer an interactive

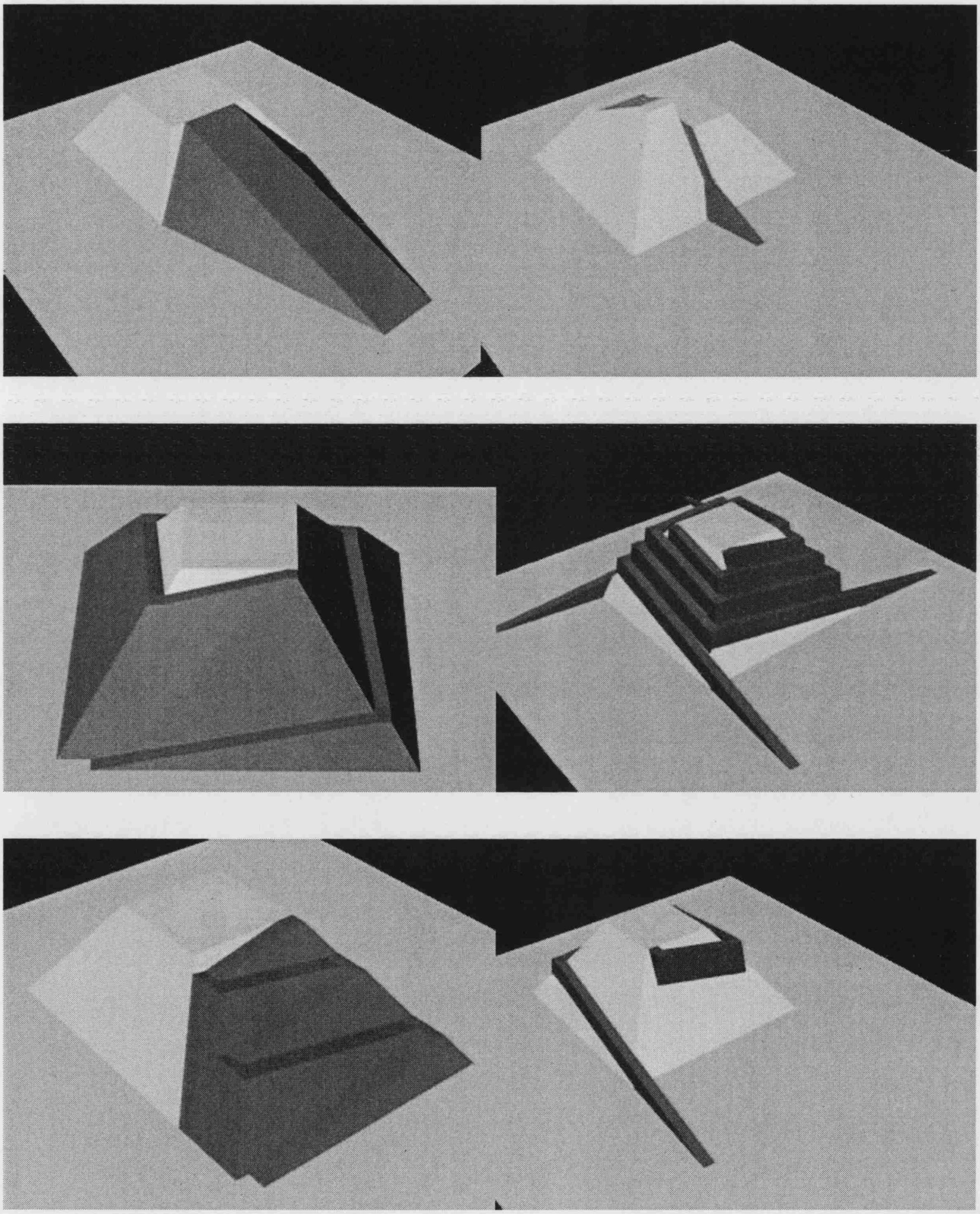


Figure 4.3.14 Exactly how the pyramids were built still remains mystery. Here are some of the possible ways suggested by archaeologists for bringing up the building stones to the construction level. There are many other possibilities, and it would be useful if the users could express their on idea using these 3D models (constructed by Narushige Shiode).

environment where the users can move the artefacts and reconstruct their own version of the site by exercising their judgement, then perhaps we could provide a more flexible impression. Section 5.2 will discuss a truly interactive environment in which multiple users can change the attributes of the environment.

In terms of the user interface, the surveys suggested that the structure of the project site should be kept as simple and user-friendly as possible, to enable an easier navigation. The ability to offer a range of contents sufficient to encourage the users to return to the site may have the opposite effect of making the site more complex and less intuitive. The only feasible remedy for this issue was to identify appropriate trade-offs, and also to provide as many alternative paths (including search functions) to each page as possible to increase the connectivity among the contents.

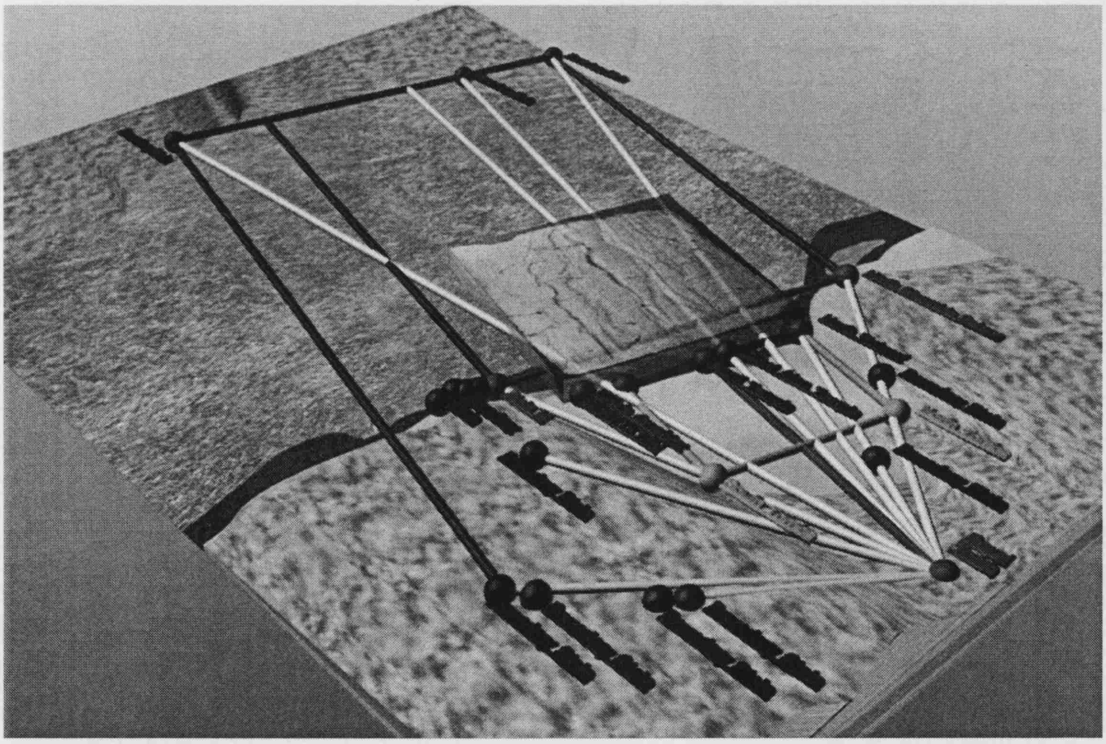


Figure 4.3.15 There is a theory on the significance of the geometric alignment of major features in Amarna (royal tomb, Great Temple, Small Temple and King's House, Boundary Stelae). This schematic model of the Amarna landscape builds on this theory, by projecting the principal motif of Amarna Art (worship of the sun disk by the king, his wife and his daughters) onto the conceptual lines between the major monuments at the site (Boston 1999, Grajetzki and Shiode 2003) (constructed by Narushige Shiode).

The 3D VR models can be also utilised in visualising ideas that are otherwise not visible. For instance, there is a theory on the significance in the arrangement of the major monuments at the site of Amarna (Figure 4.3.15) where the lines found in the principal motif of Amarna Art coincides with those between the actual monuments. By superimposing the Amarna motif onto the landscape of Amarna, we can discuss the level of similarity there in an objective manner, thus contributing to the construction of a healthy discussion in the field of Egyptology. Use of 3D VR scenes in applications will be discussed further in Section 5.1 from the planning perspective.

CHAPTER V

INFORMATION SPACE AND PLANNING

Planning and Visualising 3D Cities Online

5. INFORMATION SPACE AND PLANNING

The previous chapter focused on the use of information spaces as a tool for virtual art experiences and online learning. Each case study proposed an innovative application that utilises the flexible spatial characteristics of information spaces. Much of these applications have been previously impossible or difficult to carry out in the rigid space of the real world. It illustrates how information spaces could enhance some of our social-economic activities.

This chapter will expand on the use of information space in such manner, and it also discusses the context in which information spaces relate to and complement the real world. Section 5.1 will review the different ways that can be used for digitally representing the real world. It illustrates the range of techniques employed in the geovisualisation of the existing urban systems in an information space. The discussion of utilising information space for planning and decision making is continued in Section 5.2; where a proto-type of spatial decision support system is proposed. Section 5.3 then summarises this discussion on the planning and decision making in information spaces by evaluating the impact of digital revolution on the paradigm of planning in general.

5.1 Geovisualisation of Cities and Urban Environments in Information Spaces

5.1.1 3D City Models as Visualisation Efforts in Information Spaces

In the field of planning and designing, the growth of ICT and information spaces has helped the development of a variety of tools and technologies that support different stages of their implementation (Delaney 2000). These include

(a) rapid and effective storage and retrieval of information; e.g. GIS and Internet Mapping Server,

(b) various kinds of visualisation to inform survey and analysis; e.g. 3D city models, and

(c) different strategies for communicating information and plans to the affected community; e.g. planning support systems and decision support systems.

We owe the emergence of such planning tools to various developers and user groups — central and local governments, urban and rural planners, environmental agencies, telecommunications and utility companies, consultants, market surveyors, architects and engineers — who all utilise the increasingly sophisticated 3D city models and GIS in order to plan and monitor their services and impacts (Batty *et al.* 2001).

The combination of diverse modelling techniques and the multiplicity of their applications lead us to the emergence of a very wide range of visualisation efforts practiced in information spaces. Many of these models are being independently developed with different technologies under different initiatives to serve highly specialised purposes (Shiode 2001). However, besides their use in their designated applications, some of these models are capable of helping us understand the urban structure as well as the mechanism of urban growth, spatial analysis and planning in a broader context. The use of information space as a projection surface is particularly powerful when visualising urban and built environments, giving the option to deliver the relevant information in an intuitively comprehensive form of 3D city models with the possibility of being integrated with the relevant spatial database (Day 1994).

So far, lack of coherence amongst these individual efforts has prevented the formation of a standard modelling paradigm that can conceive such market. In fact, apart from those produced by their immediate competitors within their own specialised field, many tend to overlook the results in the other related industries; thence not building a constructive competition but merely incurring variations, which, in turn, may hinder the development of online and digital modelling technology as a whole (Shiode 2001).

This section aims to set the typology of these independent movements under a single framework and seek a coherent structure in which each modelling project could be fitted, so as to lay the foundation for developing an online-multiuse planning support system (Section 5.2). Section 5.1.2 identifies demands for the recent development of 3D modelling methods, especially of those which utilise the nature of online modelling techniques. This is followed by a summary on the activities that digital tools can support, with an emphasis on the methods of visualisation and the integration of 2D mapping and 3D-block modelling within information space. Some state-of-the-art cases are drawn to illustrate the rapid changes that are recently taking place worldwide in the ways such visualisations are being developed.

5.1.2 Demands for the Visualisation of the Built Environment

Ever since our society came to form urban agglomerations, there has been a constant manifestation of interest in the study of urban environment. Yet in geographic studies, urban geography has been regarded as less topical in comparison to the other more established fields (Carter 1995).

This can be explained partly by the nature of urban environment that comprises a number of elements from landscape modelling to various social-economic exchanges. As each element plays its own role in the formation of an urban structure, every city possesses a unique structure governed by its own momentum, thus presenting entities that are occasionally regarded as too diverse for a single topical study. Nevertheless, "*geography is not about the precise analysis of particular service areas... it is more concerned with the ways in which these relationships are reflected in the functional and physical structure of the town*" (Dickinson 1959).

Aside from the conventional approaches of the environmental determinism, regional science, and critical science (Knox and McCarthy 2005), two approaches have been pursued in the past to understand the underlying forces of urban growth: (1) the symbolic and analytical approach of geomorphology and spatial modelling for interpreting the urban society as quantitative phenomena, and (2) the iconic and empirical approach of data mining and landscape visualisation with a focus on context-specific designing of urban environment (Batty *et al.* 2001, Kaplan *et al.* 2004).

The former has been rigorously pursued during the 1960s and from then on, where there has been a continuous search for the theoretical ground to address the conjectures and remarks for urban environment. The latter was also being explored alongside it but mainly from an empirical perspective. Constructing a model was a time-consuming and labour-intensive task in earlier days, let alone the visualisation of the 3D representation (Lowry 1965). Apart from some noble attempts through photomontage, architectural parse drafting, and the conventional wood-block modelling, it has been only since the rise of ICTs that we could create mass-scale urban models in the digital form (Delaney 2000).

The initial methods of designing such models were based on computer-aided architectural design where detailed measurement of the geometry was essential. Most of them failed to offer any analytical functions, but they became available with the outbreak of

GIS technology. GIS has been intimately associated with our ability to visualise spatial data in maps and the related statistical forms, especially for those with irregular and diverse contents such as the urban landscape (Okunuki 2001). The recent development in ICTs has extended this further to the direction of 3D visualisation where our ability to render complex geometry has now become routinely embedded in standard software. At the same time, rendering techniques based on new methods of imaging such as airborne remote sensing and photo-realistic imagery are also being increasingly incorporated into such visualisations (Campbell 2001).

Increase in the supply of remotely-sensed data concerning the 3D environment also helped to make 3D visualisations of cities more feasible and popular (Teicholz 2000). They came with developments in geomatic engineering and GIS to meet the demands for application of models for querying spatial data structures, and visualising the results of such queries in the 3D form (Fuchs 1996). However, their capacity to accommodate near real-time interaction has been realised only after the development of information spaces where these models became available online for immediate interaction amongst multiple users online.

5.1.3 A Typology of Urban Data and Modelling Methods

There are a number of factors concerning 3D city models, such as clients, application, the expected output, budget, time period, and the amount of area to be covered. Aside from their capacity to be shared amongst multiple users through the information space, we also find at least three elements in the construction of the models alone: the degree of reality or the level of details, types of data input, and the degree of functionality and the ability to conduct various analyses. The range of variety demonstrated within each factor is reflected in the diversity of the current modelling technologies.

(1) *The degree of reality – the amount of geometric content*

The degree of reality is conceived by the amount of details captured and reproduced within the model. Naturally, the more details there are in the model, the more cost is incurred. However, the amount of geometrical details does not necessarily reflect how much reality the model can actually offer; in fact, rapid and inexpensive modelling techniques such as texture mapping and panoramic-image capturing prove to be successful with the general

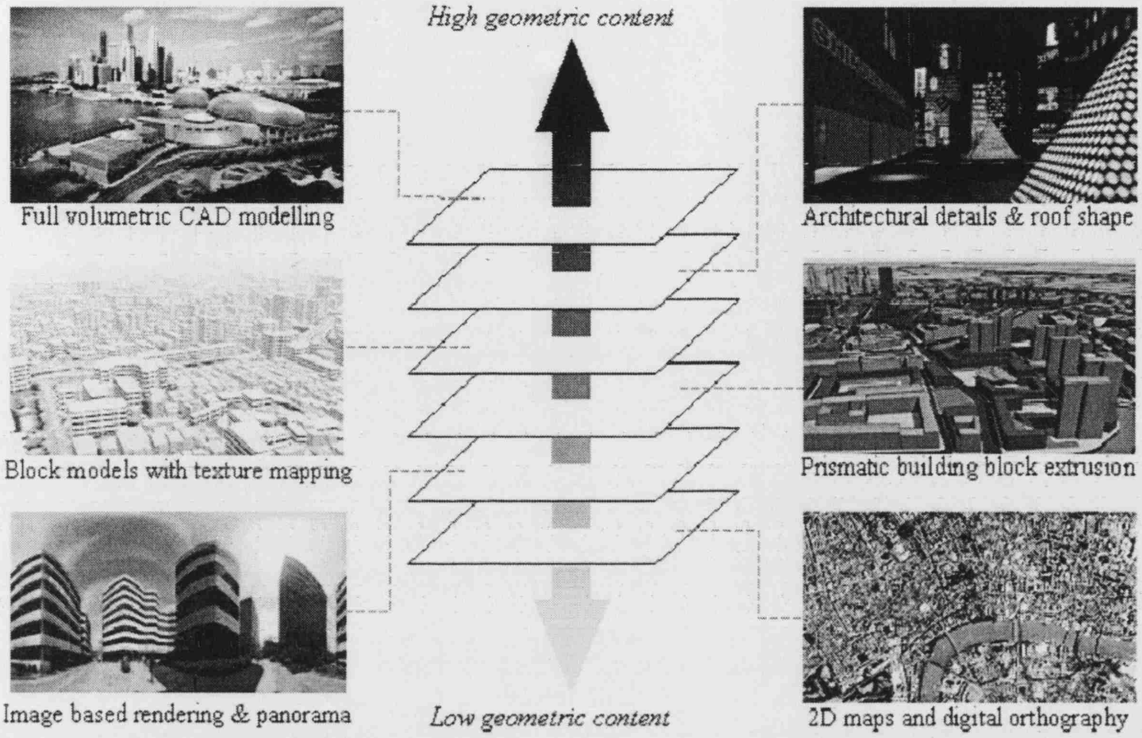


Figure 5.1.1 A typology of 3D city models using different modelling methods (Shiode 2001).

audience (Leavitt 1999). Figure 5.1.1 shows a summary of model typology in terms of the difference in geometrical details as described below (Shiode 2001).

(a) 2D digital maps and digital ortho-rectified photographs: Conventional 2D GIS maps support a range of application and data that can be easily shared amongst the different users online. However, they are incapable of giving the intuitively comprehensive 3D representation.

(b) Image-based rendering: Panoramic image-based modelling is an inexpensive solution for psuedo-3D visualisation, which offers a static view from selected standpoints. Different users can share the identical view from the same, predetermined viewpoints. Nevertheless, the number of shots taken will limit its viewpoints, and it would certainly not allow its users to *walk* about in the space represented.

(c) Prismatic building block models: Block extrusion is a fusion of 2D building footprints with airborne survey data and other height resource. GIS technology allows us to overlay 2D maps on airborne data and determine the spatial characteristics of the image within each building footprint. They lack the architectural detail and convey no compelling sense of the environment but are sufficient for analysing view sheds and the shortest path. They would also satisfy the minimal conditions as a 3D environment in which users can virtually experience the spatial extent of its invented urban environment.

(d) Block modelling with image-based texture mapping: These are similar to the prismatic building block models but with image-based facades. The building textures are most commonly generated from either oblique aerial or terrestrial images which, in most cases, successfully compensate for the simplification of the outline of building geometry and roof morphology. They offer a good balance between the level of complexity and the degree of realistic feel for their users; thus being a popular choice for many cyber cities and online communities as a descriptive method of their world.

(e) Models with architectural details and roof morphology: Modern digital photogrammetric systems enable an efficient recovery of 3D surface details. Automated search techniques are used for identifying the corresponding locations (points, edges and regions) in multiple, overlapping images to generate a number of possible geometries which can be tested against templates. However, the matching technique lacks sophistication and still requires significant amount of manual intervention for architecturally rich contents.

(f) Full volumetric CAD models: As-built CAD models of individual buildings are frequently undertaken by a combination of measured building survey and terrestrial photogrammetry. The complexity of such models range from digital ortho-rectified photographs (in which images are rectified and combined to remove perspective effects) to the full architectural details, but the cost would be prohibitively expensive for full city coverage.

Each of these methods clearly has its own advantages and weaknesses—and is suitable for specific purposes. They also offer different level of spatial awareness to their users.

Types of Data Input: Capturing Heights and Facade Information

The way the source data are obtained also affects the representation of the model. For instance, a limited number of panoramic shots are unlikely to convey a strong sense of spatial awareness, whereas airborne survey data provide geometrically accurate but less photo-realistic models. Here are some of the data-acquiring methods that are commonly used in the context of urban modelling.

(a) Terrestrial images: Still images of building facades and video recordings of street-scapes are widely used to provide surface information. Obtaining suitable viewpoints for image acquisition in a city centre may be problematic much due to restrictions on the flight paths of a helicopter or access to rooftops. Building textures are thus generated, in most cases, from ground level photographs that often fail to provide optimal facade coverage.

(b) Panoramic photographs: A panoramic image provides a highly realistic visualisation to all angles from a static viewpoint within the survey area (Figure 5.1.2). If captured with sufficient density, they can provide a very detailed representation of an urban area complete with people, vehicle and street furniture often omitted in 3D CAD models. However, it has the major defect of being fixed to a single viewpoint, which prohibits any movement or exploration of that space.

Figure 5.1.2 Digital panoramic visualisation by Webscape (*www.webscape.com*).

(c) Aerial photographs: The range of aerial survey data is becoming richer and affordable. It provides a rapid and efficient method for the coverage of a wide city area. In order to describe the building facades in detail, oblique aerial images must be acquired rather than the conventional, near-vertical aerial images.

(d) Range imaging: Range images can be treated as surfaces over which high-resolution images can be draped, thus enabling a semi-automated construction of realistic views of the object. The LIDAR (LIght Detection And Ranging) imaging techniques, in particular, are based upon camera systems that use a pulsed laser device to record the distance from the camera to each point in the image (Figure 5.1.3).

Common applications use either ground based or airborne sensors, the former being suitable for architectural surveys and the latter for small-scale surveys including city models. Airborne LIDAR is used in conjunction with the GPS (Global Positioning System) to deliver high-resolution digital elevation models. Their data invariably

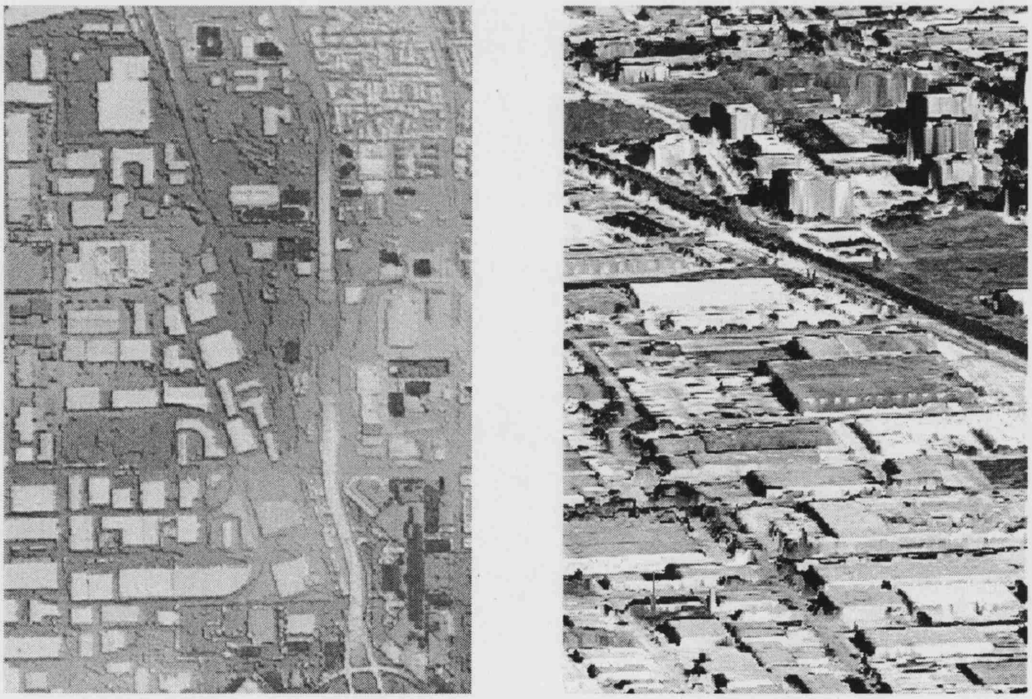


Figure 5.1.3 LIDAR-based city models. The image on the right is a direct result of an automatic extrusion of the ground surface, based on the information obtained through LIDAR. Errors are particularly evident along the edges of buildings and streets (http://www.globalgeodata.com/bldgdata.html).

contain errors and will thus require adequate data processing before being used for 3D city models (cf. Figure 5.1.3), but this is improving with the recent development of powerful software such as Mutigen Creator and Erdas Imagine.

Functionality: The Degree of Utility and Analytical Features

In terms of application and market demands, perhaps the most crucial feature is the functionality. Photo-realistic CAD-type models and CG parses are often less functional whereas GIS-based models are generally supported by substantial attribute data and are integral to some analysis. Here are some of the model types with different degree of functionality. While the amount of analytical features does not necessarily determine the usefulness of a model in its proprietary context, the potential for extensive and alternative use will be directly reflected where GIS will prove to be powerful (Holtier *et al.* 2000).

(a) Aesthetic models: Models that are intended for aesthetic appreciation and demonstrative purposes tend to have little analytical functionality irrespective of its degree of reality. They are intended for illustrating the plans and developments to the authorities, various neighbourhood groups, or the customers in general through 3D visual presence.

(b) Proprietary models with limited analytical capabilities: Typically, a model is equipped with at least one or more analytical features to serve its purpose. These include view-shed analysis as well as support for a basic planning process, or basic querying features, which are performed through its built-in analytical tools. These models are usually designed to be self-conclusive and are not suitable for extensive analysis that requires additional data to reside behind the model.

(c) Full analytical features: Models extruded from a 2D GIS dataset often benefit from the use of the full GIS functionality by inheriting the attribute data attached to the spatial objects within the initial model (Figure 5.1.4). The ranges of functions that can be performed in these models include multiple spatial queries, view-shed and shadow analysis, and various scenario-based simulations; and these models are further extendable in terms of its analytical potentials.

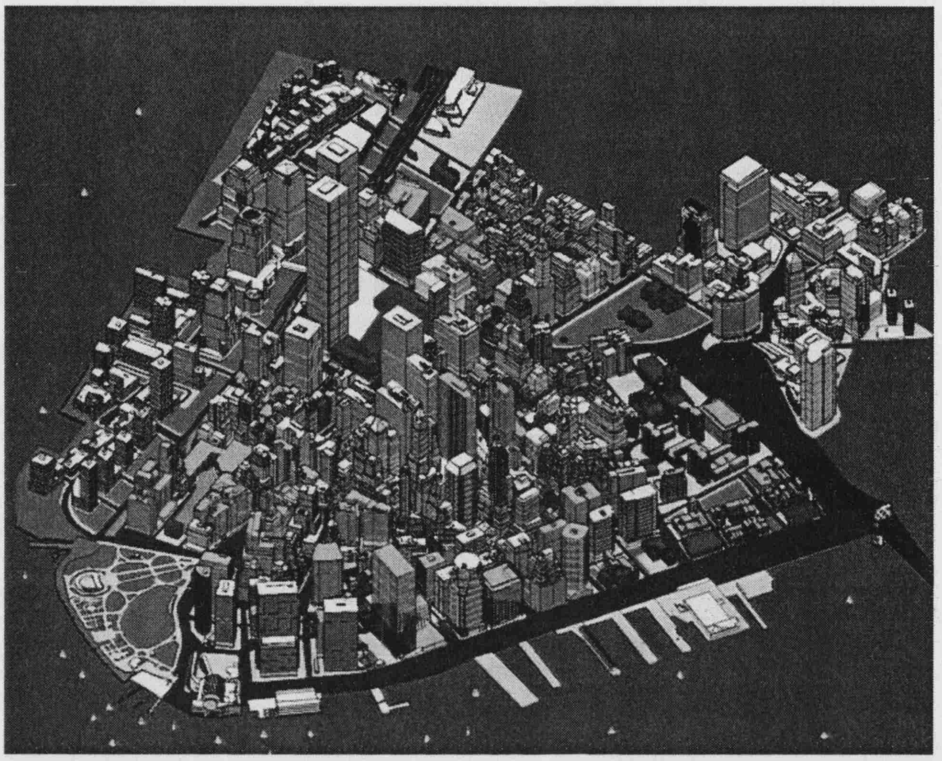


Figure 5.1.4 The Environmental Simulation Center model with the floorspace in downtown Manhattan (Copyright 1999: Environment Simulation Center).

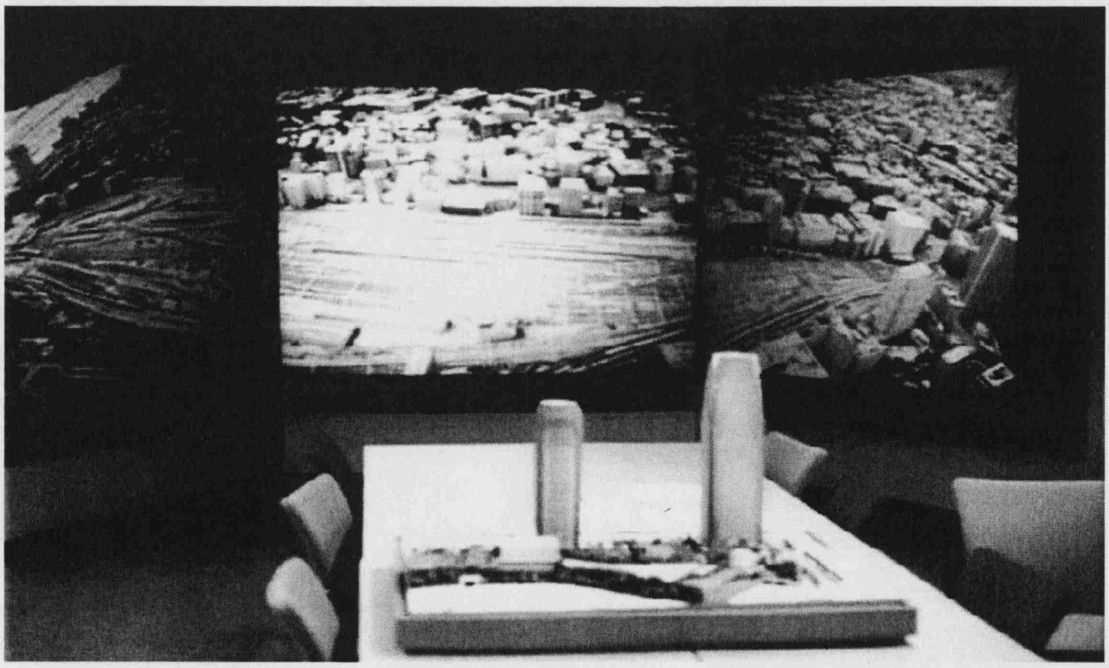


Figure 5.1.5 A hybrid model of Tokyo developed by Mori-building Corporation (photograph taken by Shiode at the Headquarter of Mori Corporation) (Shiode 2001).

(d) Hybrid models and related techniques: Some models are built as a hybrid between 3D digital model and other media. In some instances, physical wood block models are still in use where a digital model has been built alongside or on top of the traditional wooden model and the two models can be used simultaneously to complement each other (Figure 5.1.5). The notion of developing 3D models using VR displays acknowledges this role; the idea of building and displaying such a model in VR environment implies the interaction of users with the model using digital simulations of the physical movement of objects within it.

5.1.4 Applications for the Online 3D City Models

There is a significant amount of professional interest as well as commercial incentives put into the field of online and digital modelling of a 3D environment. A survey conducted by Batty *et al.* (2001) indicate that there were over 60 of large-scale projects worldwide as of March 2000, each of which modelling a part of an existing city. While the two best developed sets of applications were found in New York and Tokyo, the UCLA model of Los Angeles stood out as the most elaborate singly developed model, both in terms of its realistic visualisation and also for its highly interactive environment (Liggett and Jepson 1995, Jepson and Friedman 1998). Since then, new development in 3D GIS, as in CASA's Virtual London model, have advanced the field much further with many of these techniques beginning to merge (see Hudson-Smith, Evans and Batty, 2005).

The details of the abovementioned survey are described in Batty *et al.* (2001), but during the course of the survey, it became increasingly clear that most of these models were being developed for a very wide range of applications. Four different categories of applications can be identified: (1) planning and design, (2) infrastructure and facility services, (3) commercial sector and marketing, and (4) promotion and learning of information on cities.

(a) *Planning and Design*: Planning and design reviews as well as site selection, community planning and public participation all require, and are informed by, 3D visualisation. The focus is set upon aesthetic considerations of landscapes including daylight and line-of-sight. Visual representation of environmental impact is also widely supported by 3D models. This concerns various kinds of hazard to be

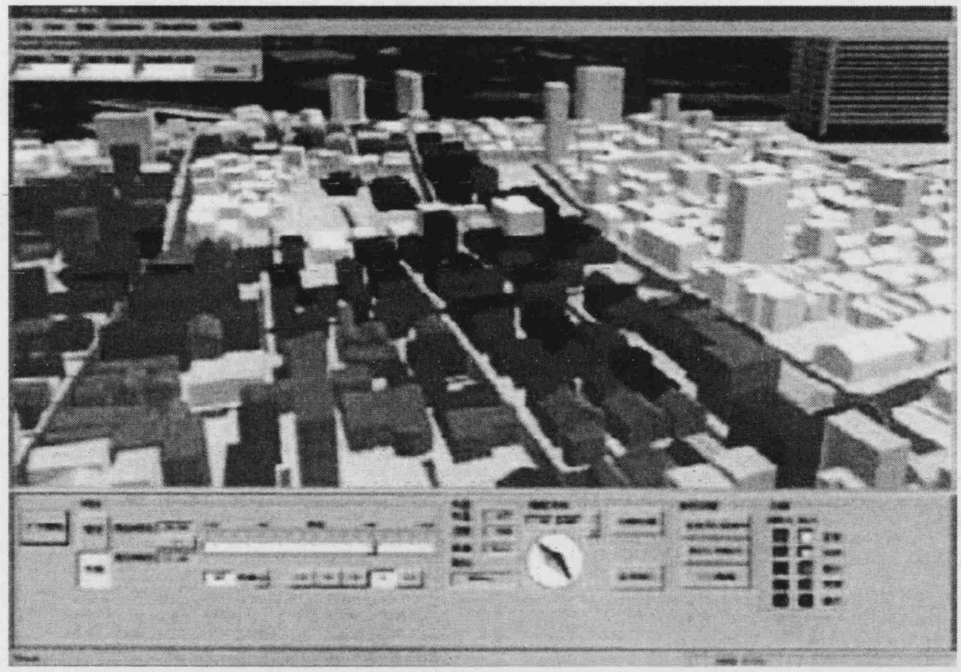


Figure 5.1.6 Firespread simulation by CAD Center
(Copyright 1998: CAD Center).

visualised and planned for, and ways of visualising the impact of disasters as well as local pollutants at a fine scale (Figure 5.1.6).

(b) *Infrastructures and Facility Services*: Urban infrastructure such as water, sewerage, and electricity as well as the road and rail network all require detailed 2D and 3D data for their management and maintenance. The analysis of sight-lines for mobile and fixed communications is also crucial in environments dominated by high buildings to secure a clear reception of signals. In addition, analysis and visualisation of access route to various locations by the police, fire, ambulance and other emergency services are crucial for maintaining a safe environment.

(c) *Commercial Sector and Marketing*: 2D and 3D models are effective for visualising the locations of the land-use types, spatial distribution of the clients and market demands for specific economic activities as well as the availability of space for development (Figure 5.1.7).

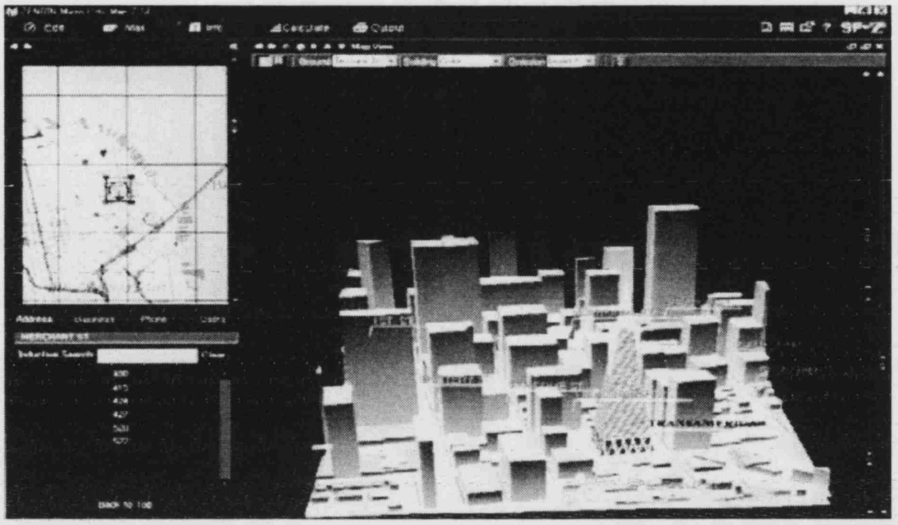


Figure 5.1.7 3D marketing analysis tool from Zenrin Corporation (Copyright 1999: Zenrin).

They also enable the computation of detailed data concerning floor-space and land availability as well as land values and costs of development. Finally, virtual city models in 2D and 3D provide portals to virtual commerce through semi-realistic entries to remote trading and other commercial domains.

(d) *Promotion and Learning of Information on Cities*: 3D visualisation offers entries to urban information hubs where users at different levels of education can learn about the city as well as to give access to other learning resources through the metaphor of the city (Figure 5.1.8 overleaf). In particular, it provides methods for displaying the tourist attractions of cities as well as ways in which tourists and other newcomers can learn about the geography of the city.

The applications clearly vary from one another, but they share one common feature in that the GIS technology plays a crucial role in their modelling process from data capturing to utilisation and maintenance of the product.

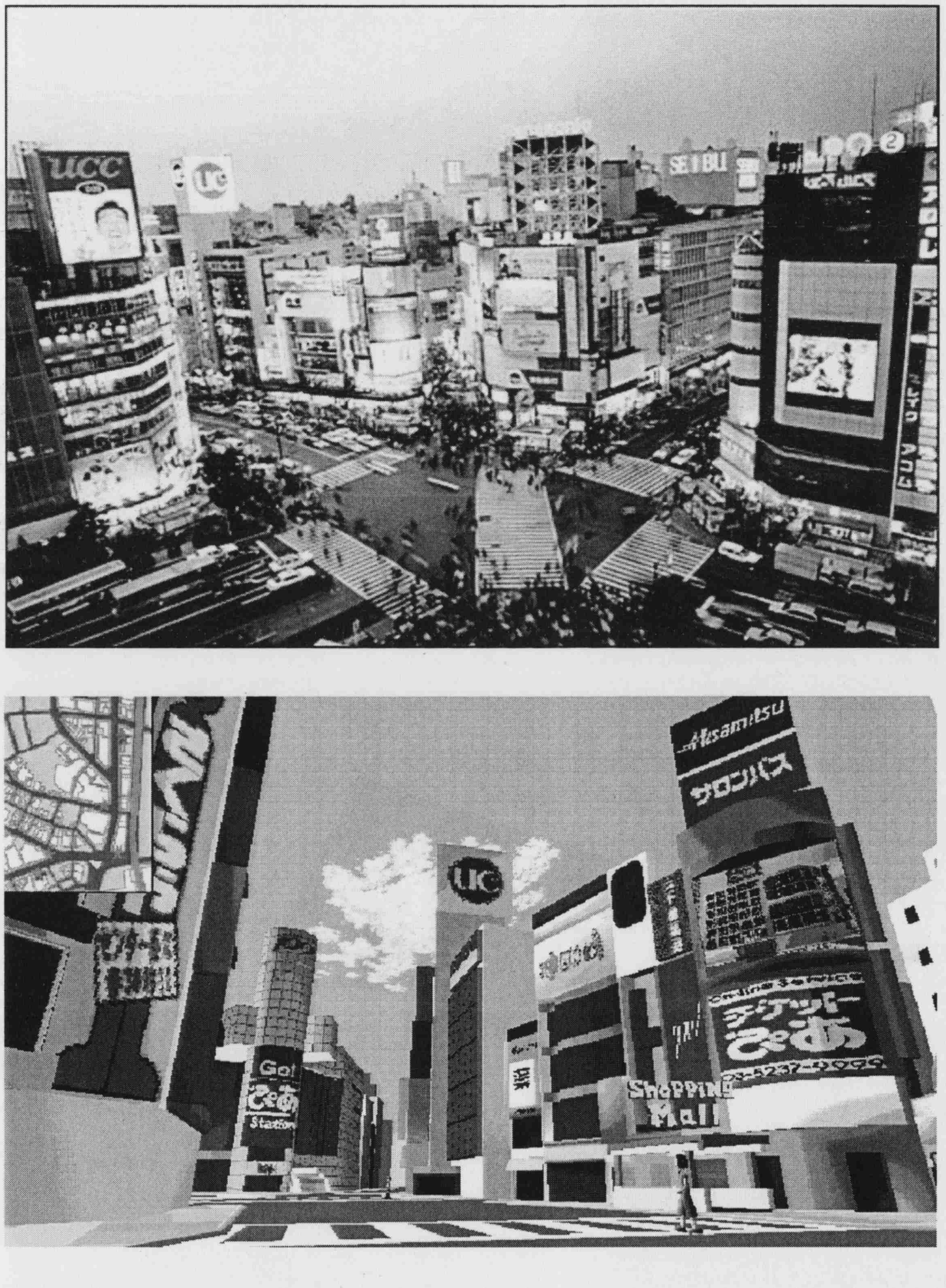


Figure 5.1.8 City promotion site for Shibuya City, Tokyo (Shiode 2001). The upper image is from the actual townscape and the lower image shows the 3D model of the same district.

5.1.5 A Framework for the Construction of an Online 3D City Model

We have seen that the 3D modelling scenes benefit from the extensive functionality and the analytical capability of GIS as well as their virtual representation in the information space. Development of 3D city models currently depends on two elements: geo-spatial database and remote sensing technology (Holtier, Steadman and Smith 2000). The rapid rate of ICT deployment suggests that these two features may become an integral part of 3D city models in the near future. Consequently, a real-time, automated modelling technology is likely to evolve, which enables us to automatically generate a model onsite wherever the remote sensing data are acquired (Shiode 2001). They will be downloaded into standard packages that generate effective and useful models in a shared environment online. These technological advancements of modelling features seem to be a matter of time, closely following the development of geographical information technologies, and the crucial factor will be the extent to which such automation will extend to bespoke applications, particularly those that address professional concerns. In this respect, specialist and unique adaptations of general principles are likely to remain the norm. However, a new breed of software capable of generating 3D city models is currently being developed. This is already the case with the plug-ins and extensions to desktop GIS such as ArcGIS 9.0, and rapid 3D modelling packages such as ImageModeler by RealViz. More elaborate systems incorporating software such as Multigen Paradigm may also become available to a wider market, as will software and data systems for producing remotely sensed data of good quality such as LIDAR (Snyder and Jepson 1999).

The way these models will be delivered is also likely to change. So far, CAD and 3D technologies on the Internet has not moved as fast as expected, much due to the cumbersome, non-intuitive interfaces and lack of 'killer applications' (Leavitt 1999). But these are likely to be soon resolved as *e*-commerce is rapidly reaching out for the market for elaborate interfaces for the use in the information space (Gilder 2000). Cumbersome and proprietary desktop software will be complemented by the Internet such as the Internet Map Server and VRML/X3D-like browsers become standard. Remote access to data as well as the real-time generation of the contents over the network is likely to become the norm within the next decade. This will open the path to an entirely new way in which users can interact with such models, and it will herald new ways in which the wider public will be able to participate, which in turn will affect the entire scene of planning (Section 5.3).

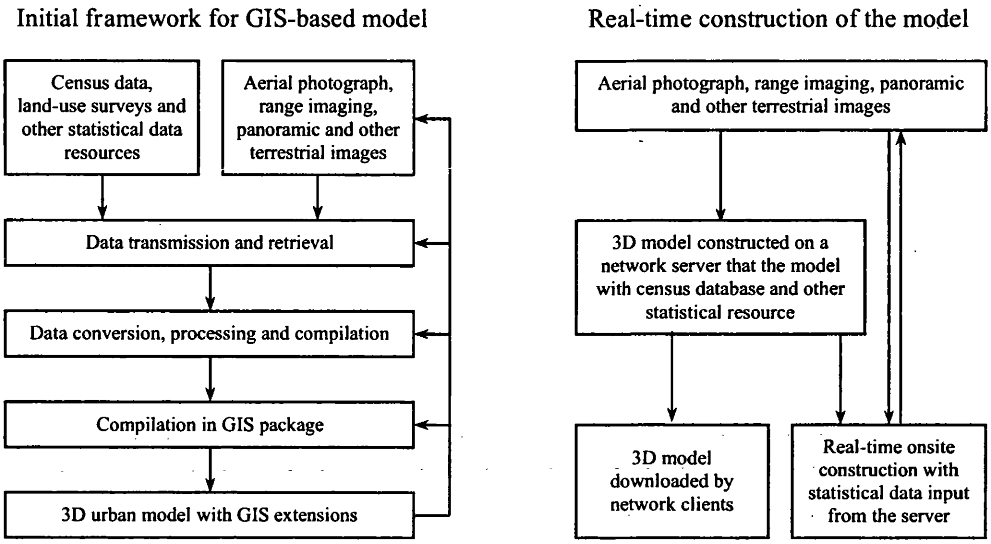


Figure 5.1.9 A comparison of the framework of the current 3D city model construction process to that based on real-time online technology (Shiode 2001).

The transition to ortho-photos and LIDAR-type systems for recording height data is also notable. Most of the models we examined no longer use manually intensive methods for measuring and recording height data. Various kinds of photogrammetry technologies are now considered essential in the construction of such models, as they support the automation of the entire process. Figure 5.1.9 illustrates the conceptual framework for real-time online construction of 3D GIS model as compared to that of the conventional models. Here data input and output are no more a time-consuming or complicating process but can be almost instantaneously achieved through the network. The model would be actually built onsite in real-time so that we can directly reflect the data input onto the model as they are captured, which provides feedback to the data input and will thus significantly reduce the time and cost of constructing the final product.

Another interesting feature of some model development is the continued use of physical iconic models, usually constructed from balsa. For example, the City of London currently relies on their wooden model that is ported to many places by the Economic Development Unit for marketing purposes. They have some digital imagery associated with it, but the 'hands-on feel' the model provides is still important to its use. In Jerusalem, a digital model has been built alongside the traditional wooden model and there is interaction between the two in usage to evaluate development proposals. Also, Mori Corporation, Tokyo, Japan, utilises their 1:1,000-scale model of Tokyo by showing its image on digital display (Figure 5.1.5). Similar effort has been made in Liverpool, UK to build a digital model of the city centre from detailed scanning of the traditional wooden model, thus by-passing the need for digital photogrammetry (Wooley 2000).

5.1.6 Summary of Findings on Online 3D City Models

This section categorised a variety of city modelling methods that have been led by the recent development of information space and geo-spatial technologies. It is clear that no standards have yet been established for the entire modelling arena, despite the basic commonality shared by the various modelling approaches. In terms of two different groups of approaches seem to be emerging from this diverse range of methods.

(a) An *ad hoc* combination of in-house components — use of different software package and in-house tools of CAD, image rendering, database, and interface authoring tools. This approach is suitable for developing a proprietary model for a small area and architectural models with an emphasis on the visual representation rather than its functionality.

(b) Integration of GIS and online communication software with 3D visualisation — extrusion of vertical elements on digital map data occasionally combined with image matching techniques with aerial photograph data. This is more appropriate for large area coverage as well as spatial analysis and simulations.

The distinction between the two approaches is likely to remain, as each of them currently serves different demands and clients; the former is adopted mainly in the context of urban and architectural designing, whereas the latter is widely used in the market analysis, telecommunication and various simulations and a host of other uses.

Most of the former are either standalone models or uses a proprietary server/client system, which are more difficult to be shared in information spaces by multiple users in their original form. The GIS data of the latter type can be shared online, but their 3D model still suffers from the lack of standard multi-user interface. This presents a problem when using the model as an aid for online decision making. Some attempts have been made to export these models to a data format that can be shared and managed online (e.g. VRML/Web3D).

As these modelling methods become more sophisticated and available to a wider audience, we anticipate two conflicting movements. On the one hand, these online city models are likely to become more contents and demand specific, tailored to accommodate specific needs for each use and thus generating even more variations; while on the other hand, the demands for data and model compatibility require a standard protocol and metadata to be adopted by the 3D models. The latter is a particularly important aspect, as this will ensure the simultaneous use of the model by multiple users online. The following sections discuss issue of creating an interactive environment out of such model and utilising it for online planning use (Section 5.2) and the change in the planning profess caused by ICT deployment (Section 5.3).

It is hoped that the market will evolve on its own to discover the appropriate set of technology for different applications, but we are likely to have more than a single, unified standard as implied by the distinction between the two modelling approaches above.

5.2 Computer Supported Collaborative Environments

5.2.1 Using Information Space for a Collaborative Planning and Designing Task

Pursuing Interactivity in Information Spaces

The preceding section reviewed the range of technologies used for constructing digital 3D city models. We learned that no single method or protocol has been established as standard and that different techniques are applied for models for different purposes. Regardless of the purpose of development, many of these models lacked one crucial aspect of providing multi-user, participatory environment, which distinguishes the Internet-based information space from a simple, standalone VR environment and (Section 1.2). It would be useful for us if we could share these models online with other users and also interact with their contents. For instance, in the field of planning, online access to the same 3D model by multiple users would offer an intuitively comprehensive solution for the process of urban planning and the presentation of the output (Schroeder *et al.* 2001). It would also provide a better chance of public participation where users could share a virtual space to present and discuss their ideas, and engage in a collaborative task. For instance, suppose that two people in different locations "log in" to the same server machine from their local network computer. The server would provide a digital space shared by the two users through the computer network. By manipulating their own digital representation called an avatar, they can communicate with each other in the shared information space (Schroeder 2002).

In fact, one of the main features of information spaces is the capacity to support the formation of such multi-user collaborative environment, where users accessing from different geographical locations may engage in a collaborative task and share the social dynamics of VR environment. The fact that they can be carried out in the intuitively comprehensive 3D environment as seen in the previous section (Section 5.1) makes it particularly effective as a means of conducting such tasks together. Drawing from the discussions in Sections 4.2 (interactivity) and 5.1 (3D online planning scenes), this section introduces an online, multi-user system that enables its users to collaborate with one another over the computer network.

A Case Study on Computer Supported Collaborative Works

In an attempt to explore the possibility of using information space as a means to support the planning process, this section introduces an online, multi-user system that enables collaborative work in the information space. It focuses on a case study that uses the metaphor of garden planning in the setting of a traditional Japanese temple garden on which a basic computer-supported collaborative working (CSCW) environment is built.

Figure 5.2.1 Stone Garden of Ryoanji Temple, Kyoto, in the 16th century (Okabe *et al.* 1998).

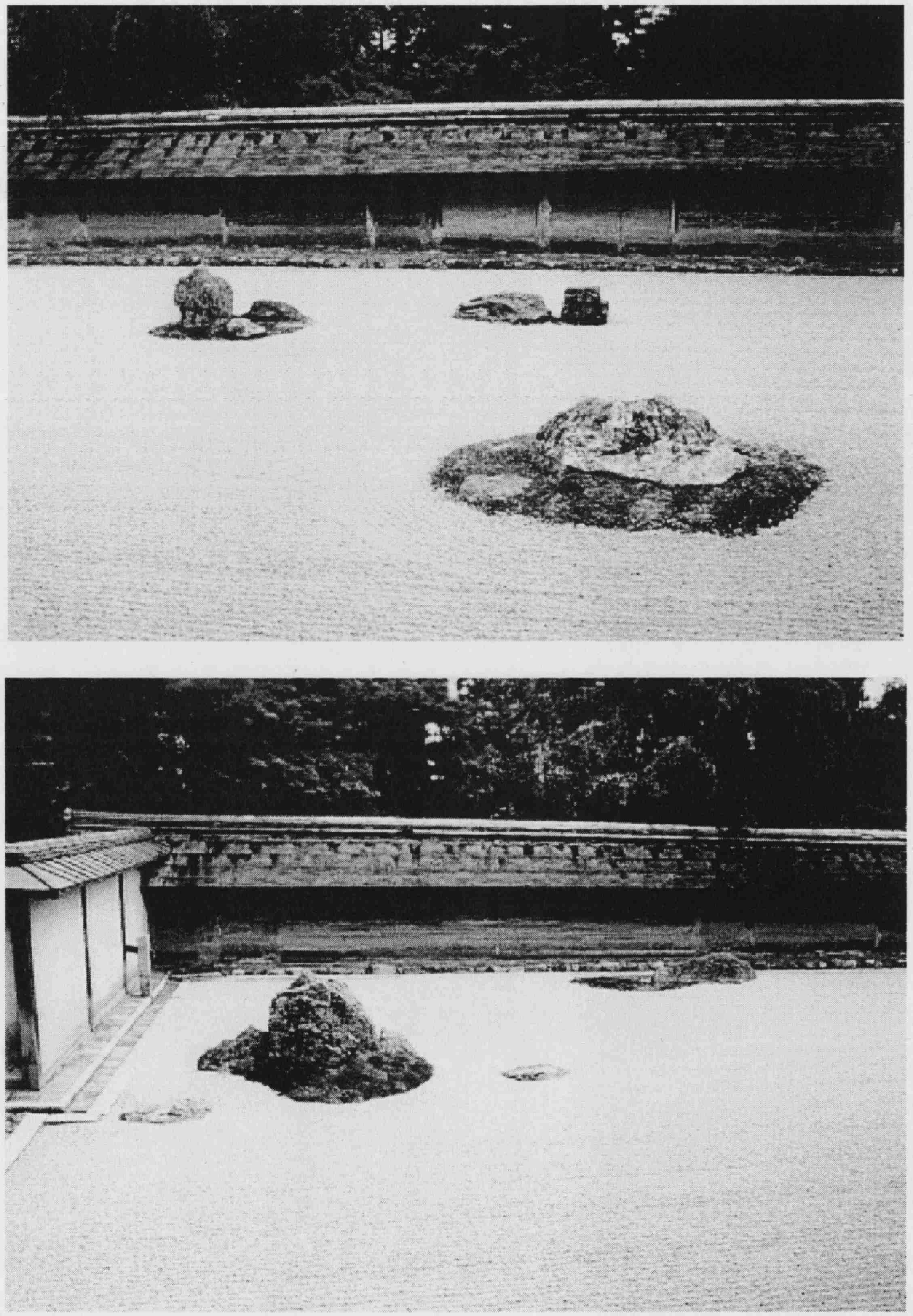


Figure 5.2.2 The stone garden of Ryoanji in modern days (Okabe *et al.* 1998).

The project was carried out from 1997 through 1998 as a joint initiative between Sony Lab. Co., Japan, University of Tokyo, and myself with the objectives of digitally reproducing the traditional Japanese garden of Ryoanji Temple, Kyoto (Figures 5.2.1, 5.2.2), and developing a multi-user network tool that allows participants in different geographical locations to carry out a collaborative work of arranging stones within this cyber garden.

Rather than trying to create a full-featured planning tool in a single step, the project was aimed at developing a relatively simple system of garden-planning, as its simplicity was thought as a perfect setting for avatars in problem solving situation. Ryoanji, Kyoto, is noted for the beauty of its stone garden originally constructed in the 16th Century. The stones are arranged on the sand bed of the garden following the Zen philosophy in such way that it would provide a healing and relaxing sensation to its visitors. Figure 5.2.1 shows an old record of the stones arrangement in Ryoanji (Figure 5.2.2 overleaf provides a more up-to-date impression of the garden photographed in 1998). Changing the arrangement of the stones—or entering the stone garden for that matter—in the real world is strictly forbidden, but we could come up with our own pattern if we were to "virtually" arrange them. The objective is to reproduce the garden in information space using VRML and to develop a Web-based multi-user tool that allows several participants in different locations to carry out a collaborative work of arranging stones within this cyber-garden. Each participant is represented with an avatar so that their presence and movements would be clearly acknowledged by the others. By controlling their own avatars, the participants could "lift," "move" and "fix" the stones to build an ideal cyber-garden of their own.

The cyber-garden model was written in VRML 2.0 and Java, and some new extensions were added to Community Place browser, Sony Co., so that the participants could interactively reflect their actions and communicate with one another. The results of each collaborative exercise were also uploaded on the Web in VRML format, accessible by anyone using a standard VRML browser; thus subject to public evaluation. Today, a wide range of applications can be found for collaborative virtual environments and CSCWs (for instance, there is an ACM Conference Series on Collaborative Virtual Environments), but there were only handful of such attempts when we conducted this study back in the late 1990s.

The details of the Ryoanji Garden planning project are described in the following sections. Section 5.2.2 explains the technical and social backgrounds of CSCWs and online planning-support systems. This is followed by the discussion of the use of information space for planning support (Section 5.2.3), the concept of the tool (Section 5.2.4), the process of arranging the stones (Section 5.2.5), and prospects of future developments (Section 5.2.6).

5.2.2 Technical Backgrounds of CSCWs

First, we will briefly review the technical background of the use of Internet services, especially that of VRML, in the planning context, which forms the basis of this project.

Elements of Internet Service

As reviewed earlier in Section 1.2, VRML was first designed just a little over a decade ago (Pesce 1992) but has rapidly become the predominantly popular format for describing 3D contents online in the mid-90s. The initial VRML technology (VRML1.0) merely displayed 3D scenes in a static manner, and these are occasionally referred to as walk-through environments. The next generation (VRML2.0) came with the ability to describe movements and play background sounds in 3D space. The multi-user technology was being built into VRML (VRML 97) just when the Ryoanji project was conceived. This allowed multiple participants to share the same 3D environment and interact with one another within information space. Since then, it has evolved to the Web3D initiative that is capable of providing a real-time, multi-user 3D world distributed on a server/client system, which was similar to what we had realized with the Ryoanji Garden Planning tool.

As 3D VR technology become widely available over the information space, the difference between the real and the virtual spaces became increasingly smaller (Mitchell 2003). The range and extent of our social-economic activities also increased as we saw improvement in the degree of our online accessibility as well as online participation (Graham and Marvin 2003). We should, however, be reminded that collaborative tasks carried out in virtual environments may not yield the result as in the real environment. In fact, several comparative studies show that people behave differently in the real and virtual worlds when conducting collaborative tasks (Slater *et al.* 1998, 2000, Axelsson *et al.* 2001). The focus of the case study here is set on utilising a VR environment for tasks that are difficult to be carried out in the real world for variety of reasons—in this particular case, the arrangement of the real stone garden is actually fixed and is not allowed for the public to modify. However, we should note that there is the danger that the result of using an online tool such as this may be different from a real-world scenario.

Use of Server and Client System

There are some other techniques that are used in the Ryoanji Garden Planning Tool. In order to control the 3D scenes and the movements within the space, we need to describe the geometric shapes and record any changes or movements at the same time. These tasks can be carried out by using VRML, HTML (Hyper Text Markup Language) and the Java language. Changes in the shared data should be also monitored and distributed so that the users within the same information space can share the most updated information in near-real time. For instance, when one user makes a movement, it should be clearly reflected in the digital space, thus allowing other users to acknowledge the change. The piece of information concerning a user's movement is thus controlled and maintained by the server machine and received by every client system (Figure 5.2.3). In case of the Ryoanji project, network-based software called Cyber Passage Bureau—originally developed by Sony for the purpose of handling shared information—was used at the server side, and a multi-user VRML browser, Community Place, also by Sony, was used for interpreting the data at the client side (Figure 5.2.4).

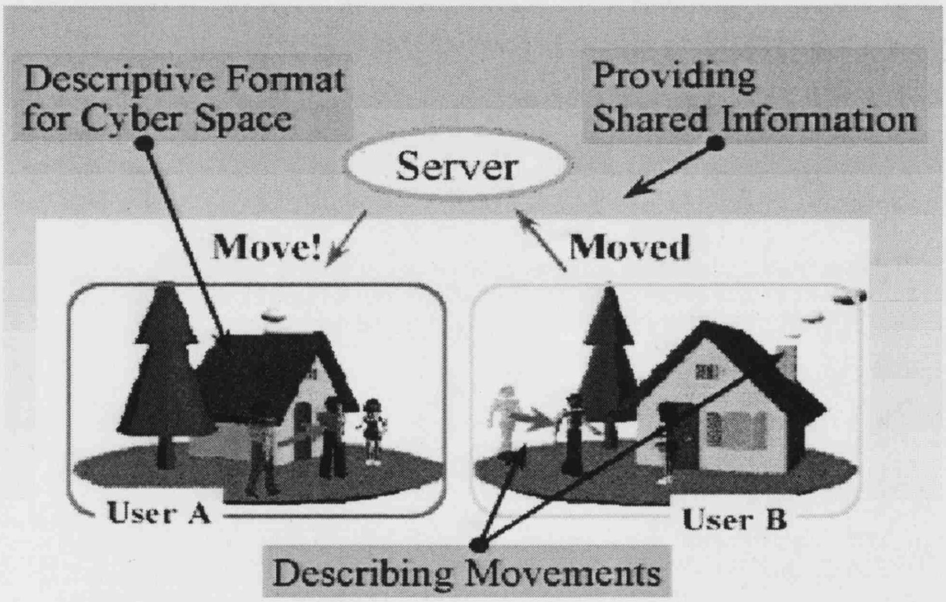


Figure 5.2.3 Sharing the information between the users logged in the same cyberspace (Okabe *et al*. 1998).

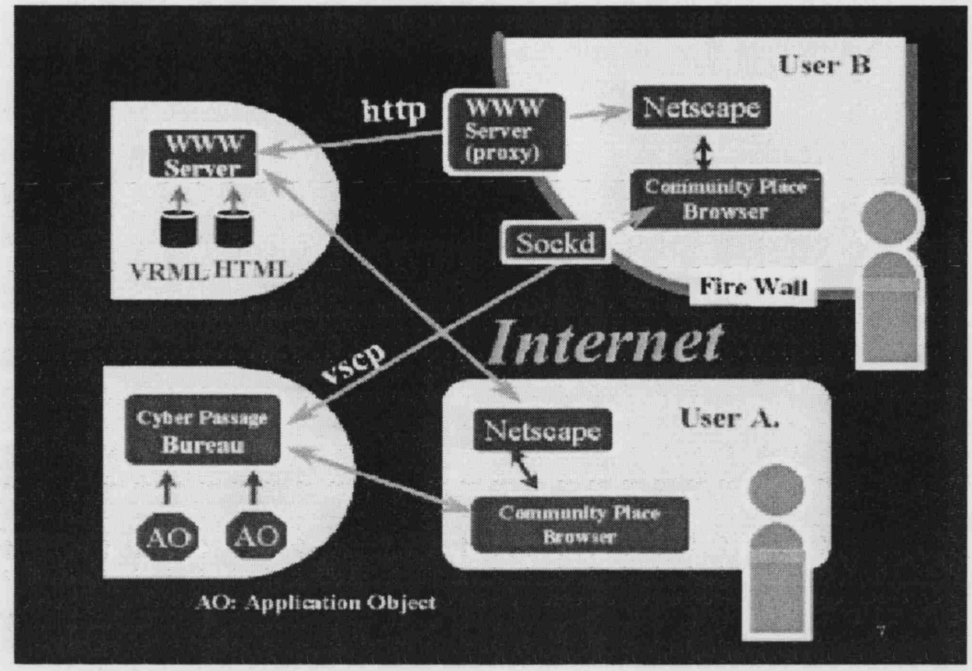


Figure 5.2.4 Mechanism of interpreting the shared information (Okabe *et al.* 1998).

5.2.3 Utilising the Internet for Urban Planning

In conjunction with the recent developments, the ICT is gradually being adopted in the field of urban planning. The advantage of using it during the planning process is that people located in different places could engage in two-way communications, and even exchange visual information in near-real-time. When the Web service was first conceived, urban planners did not make the most out of its capacity to communicate in two-ways and in real-time (Mitchell 2000, Graham 2004). The municipal government of Sapporo City, Japan, for instance, provides various planning information including their outlines, locations and duration through its Web site (Shiode 2001). However, they fail to accept feedbacks from their citizens, thus providing a rather one-sided service. Two-way communication has constantly been popular even in the pre-Web ages through various media such as news or mailing list whereas a standard Web service seems to lack this aspect. Why, then, is the Web service so highly praised? As aforementioned in Sections 4.1~4.3, the Web service is distinctively different from other Internet services for its ability to transmit multimedia contents. To some extent, whether or not urban planners use the Internet efficiently depends on how well they utilise all its features: two-way transmission, real-time communication and multimedia data manipulation through the Web service.

In fact, some governments and municipal authorities were already launching a two-way communication scheme for the planning process just as the Ryoanji project was under way. In the case of Yamato City, Japan, they summarised their urban planning problems on a map, uploaded the image onto their Web site, and accepted comments from the citizens (Kobayashi 1998, Kobayashi and Hibata 2002). They built the Town Master Plans based on the electronic and onsite feedback from their citizens and succeeded in utilising two-way multimedia communication. However, even in this case, a real-time 3D communication was not adopted.

The Ryoanji Garden Planning tool was designed to accommodate a real-time, 3D data transmission among multiple participants, which followed the prevailing trend of utilising the Internet in the planning context. In fact, when we think of a scenario under which multiple participants are asked to collaboratively carry out the task of constructing a single urban model over the network, the ability to communicate in real time and to transmit 3D contents online are almost crucial (Shiode 2001). A planning support system that supports these features would enable us to exchange plans of cities real-time in an intuitive fashion whereupon there would be less demand for all the participants to be physically present in one place at the same time.

5.2.4 Concept of the Ryoanji Garden Planning Tool

This section discusses the conceptual framework of the Ryoanji Garden Planning Tool, and how each of its process reflects the actual procedures involved in the real urban planning. As aforementioned, this project was designed as a pilot phase for the development of a full-featured planning support system. One of the essential points of urban planning is to gather a number of people, possibly with different ideas and standpoints, and to reach a consensus by repeating the discussion of alternative options; and this project was hoped to deliver some initial insights on the prospect of conducting such collaborative tasks online.

The designing of the garden planning tool takes this aspect into account and allows it to correspond, on real-time basis, to multiple participants (referred to as players hereafter) carrying out a collaborate task. In this particular context, the exchange of opinions and different actions taken by planners with different roles in a usual collaborative work are being represented by the discussions on the arrangement of the stones in a virtual garden. In order to make each player's role distinctive, each player will be assigned with a unique set of stones; the same number of stones, but in different sizes and shapes. Each stone can be moved only by the player to whom it is assigned. By restricting the interference with other player's stone, we can give different role to each player. In other words, the players can complete the task only by collaborating with each other.

The process of collaborative work consists of four steps: discussion, temporary placement, resolution and settlement. The stones would be placed one at a time, and these steps are repeated for all stones. Should, at the stage of resolution, the temporary arrangement be voted down, they should start over from the discussion. These four steps reflect the general process of urban planning (the change in the planning process due to the development of ICTs and information space will be discussed later in Section 5.3).

When all the stones are arranged and the stone garden is completed, the output will be exhibited online for public evaluation. This can be regarded as the equivalent of the public hearing process in the real planning procedure. Based on the results from public evaluation, players can return to the drawing board and re-arrange the stones. This step would be the equivalent of the feedback step in urban planning.

5.2.5 The Process of Arranging the Stones

The process of arranging each stone comprises of the following four steps:

(1) Discussion on preferable location
(2) Temporary placement
(3) Adoption of resolution
(4) Final settlement

and players are asked to follow these steps repeatedly for each stone.

Discussion

Players will first determine which stone they should work on and then discuss its preferable location. The means of communication throughout this discussion will be gestures made with their avatars as well as "chatting." Chat is one of the common methods of communicating over the Internet, which allows the users to "talk" with each other by entering their dialogue in the chat window from their console. By manipulating their own avatars, they may also move around the garden, change their viewpoints and communicate by gesture.

Temporary placement

When the discussion comes to a certain settlement, the players can try placing the stone temporarily in the garden and see the result. The number of trials for arranging each stone will be restricted to certain counts (initially up to 5 times). In other words, players can go through the process of arranging and discussing repeatedly, up to a certain times of iteration preset by the system. This trial and error would help the player to develop a common plan with the others.

A stone temporarily arranged would be expressed in pale red so that it could be distinguished from those that have been already fixed (Figures 5.2.5, 5.2.6).

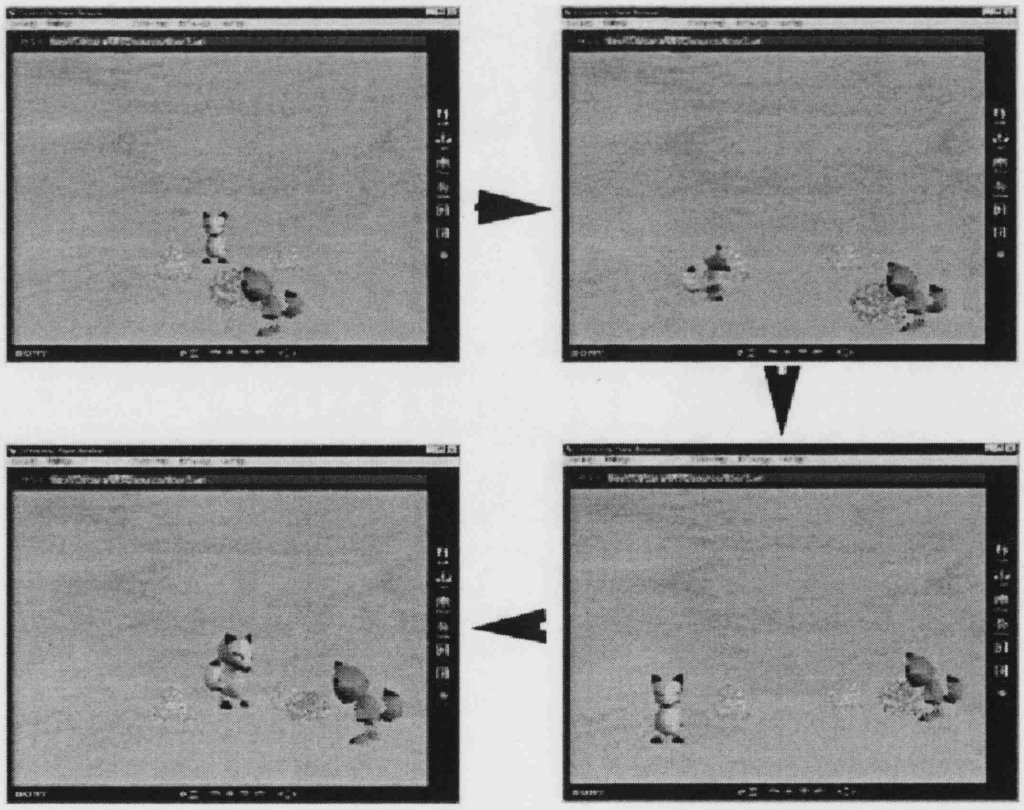


Figure 5.2.5 Arranging the stone in the main window (Okabe *et al.* 1998).

Figure 5.2.6 Communicating in real-time to decide the arrangement of stones. (Okabe *et al*. 1998).

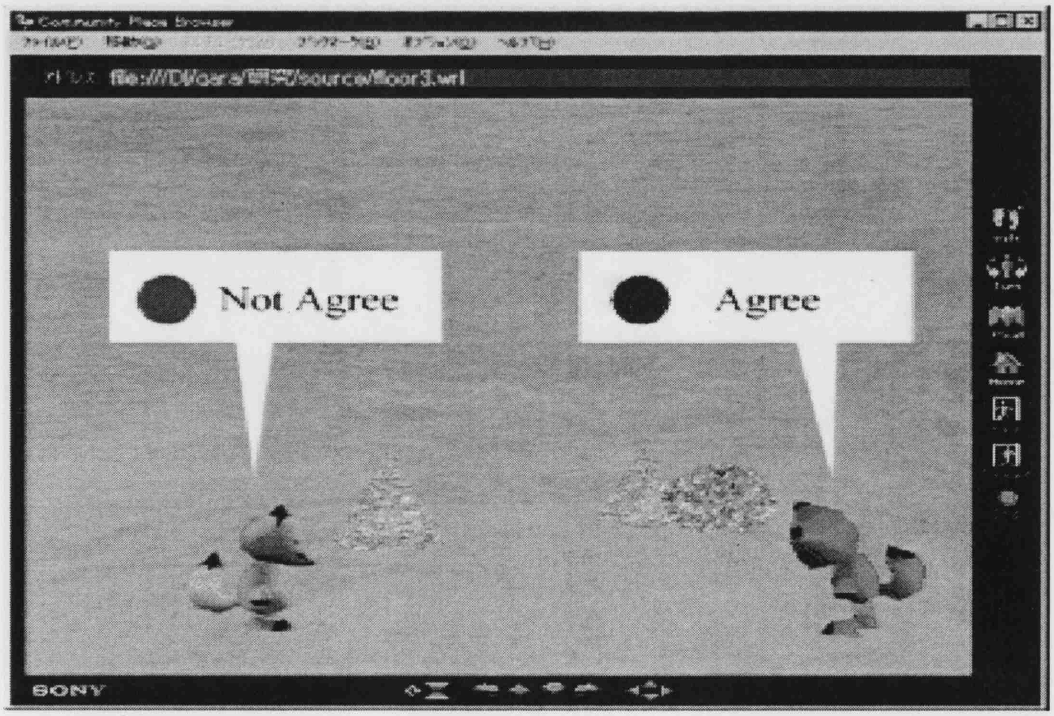


Figure 5.2.7 Communicating in real-time to reach a consensus (Okabe *et al*. 1998).

Voting

After placing the stone on a temporary basis, the players should proceed to the resolution and decide whether the temporary placement is adequate or not. It would take the form of an open vote by all the players. If the player agrees with the temporary location, he/she should click "OK" button and, if not, "NO" button shown in the window (Figure 5.2.7). The polling score between pros and cons will be displayed in a small sub-window. We adopted this voting system to avoid an arbitrary decision made by a single player. The default setting requires approval by the majority of the players for passing it. If the temporary placement is voted down, the players should start again.

Final agreement

Once the resolution is passed, the stone is no longer moveable and will be actually fixed to that location. Players cannot proceed to the arrangement of the next stone until this settlement is completed.

These four steps will be followed in the same manner for the arrangement of the remaining stones, starting off with the discussion. After going through this process for all the stones, the garden will be completed and exhibited. The works are then uploaded on a publicly accessible Web site and will be subject to public evaluation. The next section describes the method of such exhibition.

The Interface

The interface of Ryoanji Garden Planning Tool consists of four window-typed frames. Their purposes and functions are as follows (Figure 5.2.8):

(1) Main Window: The VRML scene is displayed as a 3D space in this window. Players will appear as avatars and will engage in the stone arrangements. Visitors, who are not involved in the work, can also enjoy the same scene from the corridor.

(2) Selection Window: This window displays a list of stones available. By clicking its image, players can select which stone to be used next. Once selected, the stone will appear in the main window.

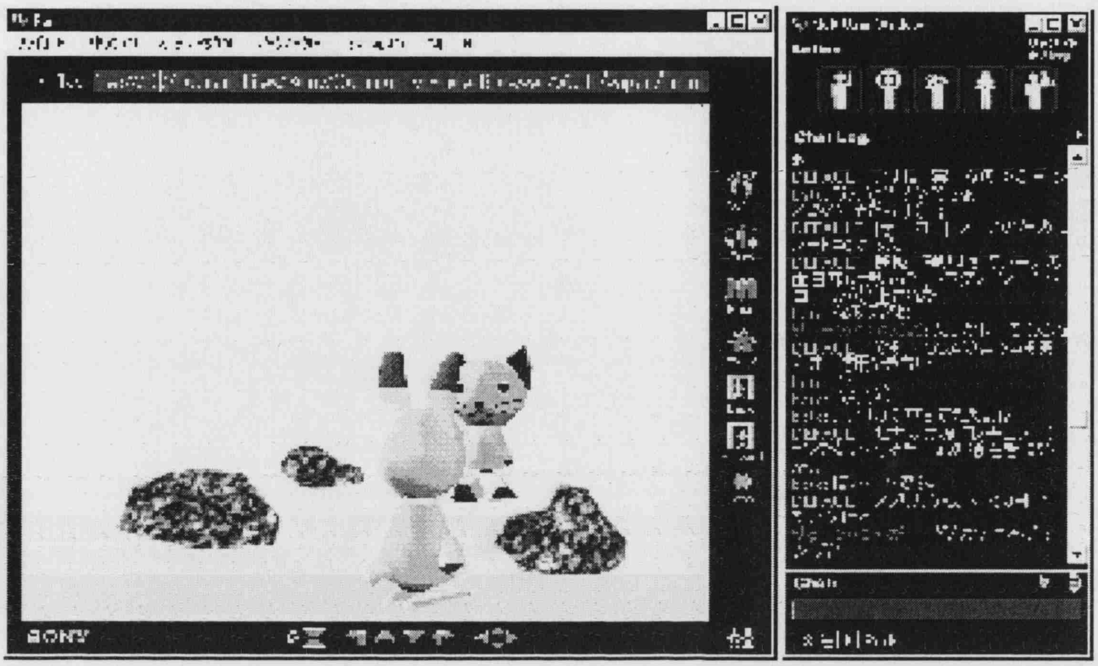


Figure 5.2.8 A snapshot of the Interface of the Ryoanji Garden Planning System.

(3) Action Window: This window is prepared for a player to make six different types of actions: grabbing, releasing, lifting up, putting down, pushing or pulling the stone. By selecting the type of action from the list, the player can manipulate her/his own avatar accordingly. Other simpler movements such as moving to any four directions, looking up and down, or rotating the body of the avatar are controlled from the console; i.e. the keyboard and mouse.

(4) Chat Window: This window shows the conversation made between the players. Visitors can also read the lines, but they cannot take part in the players' conversation. The visitors can chat with each other and reflect their opinion to the works by evaluating the completed works.

5.2.6 The Prospect of Exhibiting and Evaluating the Work

As the basic structure of the Ryoanji Garden planning tool was based on VRML and Java, there is the potential for developing an online gallery or hall in which any VRML user could browse them in the information space without actually taking part in the task. The visitors may be able to see the work in progress from the corridor as if they are watching the original Stone Garden of Ryoanji. As they proceed along the corridor, they will find different versions displayed one after another.

As they keep walking down the corridor further on, they would come across the exhibition gallery full of completed arrangements. The results are shown with the players' names and their comments. Visitors can view the completed stone gardens as if looking at pictures in an art gallery (Sagara 1999).

After looking at the gardens, visitors can reflect their evaluation by casting their vote for the best. There is no definite standard as to the evaluating process and it is solely dependent on the visitors' judgment. This is similar to the fact that there is no standard basis of judgement in urban planning, and that citizens should rely on their own judgement when evaluating the plans. The polling scores will be displayed in the Web site in real-time. We expect this public ranking will motivate the players, help us grasp the trend of evaluation, and increase the visitors' interests in participating. Unfortunately, due to time constraints, the designing of such exhibition remained at the experimental stage (Details of the exhibition of the completed arrangements can be found in Sagara, 1999).

5.2.7 Summary of Findings for the Case study on A Collaborative Task

This section proposed the development of a basic interactive software for planning a stone garden site. It was an enhanced-VRML-based, multi-user system with which participants from different locations could simultaneously "login" to the same information space and carry out a collaborative task of arranging a set of stones to form a Japanese-style temple garden.

The fact that the scenario is set on a simple task of arranging stones has its own advantages and disadvantages. On the one hand, it has a clear objective, and the results are easy to compare with one another; which makes it a perfect example for the subject of a pilot project such as this. On the other hand, lack of complexity in the process may hinder the chance of identifying potential issues for designing a full-scale planning system.

The ultimate goal of this study is to construct a multi-user interface that support planners carry out a complex urban planning processes and procedures within the information space. As Ryoanji Garden Planning Tool consists of the main planning components, it would qualify as a prototype model of a full-featured urban planning support system and gives us a good starting point.

The context of this study is specific to that of Japanese culture. However, in principle, a cross-cultural, comparative study of the aesthetic sense towards gardens can be carried out between any two cultures. For instance, the fundamental values in Japanese tone is often characterised by "*Wabi-Sabi,*" or *the nicety of beauty that exists in simplicity and subtlety.* We may find certain similarity in the cultural background of Britain and Japan such as elegant simplicity, subtlety or cosiness.

In fact, using such tools online may help us investigate the unique features of virtual society and its culture. Study of cyberspace culture, particularly in terms of the difference it holds against that in the real space, is also an important issue that should be investigated thoroughly to which an online planning tool could make a contribution. Several notable work has been conducted in this respect (Schroeder 1997, 2002, Slater *et al.* 1998, Axelsson *et al.* 2001). There are also quite a few studies on human behaviour and the psychological aspects of the real space, but whether or not these results could be applied to cyberspace remains an open question (Conroy 2000). It is hoped that the second phase of this study would improve our understanding of the unique features of the emerging virtual society.

As aforementioned, the method applied in this study is also applicable to the development of a collaborative working system for full-scale urban planning where citizens in different locations can simultaneously enjoy the construction of a virtual town as if they are building a real city (Shiode 2000). In the past, planners had to gather in one place to draw maps and build models of each option. However, with the aid of a collaborative working tool, much of the planning procedure could be carried out in information spaces with relative ease (Batty *et al.* 2002). It would significantly promote citizen participation (Laurini 2000, Kobayashi and Hibata 2002).

The concept of working together in a virtual environment has been known for some time (Jones 1998, Kapor 2004), yet there are only few planning tools that require no proprietary interface, such as virtual goggles and virtual arms, or in fact a significant amount of budget for that matter; and, in this sense, we believe that this project has a lot to offer.

The Ryoanji Garden Planning Tool is designed as the pilot phase for the development of a full-scale online planning tool. The second phase is currently under way at the

Department of Urban Engineering, the University of Tokyo (Sagara 1999). The primary objective is to develop an online multi-user environment that would enable the users to engage in a diversity of urban planning and decision-making scenarios. When fully developed, it would and should be able to accommodate the main factors and stages of the actual urban planning process. It will not only assist us with each step of the actual planning procedure, but may also contribute to the understanding of the users' behaviour and mentality within this wired space of computer network.

5.3 Information Space Planning

5.3.1 A Long-term Effect of the ICT Development

The previous two sections looked at the recent development of designing tools and planning systems in the form of 3D city models (Section 5.1) and planning-support systems that can be shared in information spaces (Section 5.2). They illustrate some of the short-term impacts of ICT development to the field of planning in that the tools available for such tasks are becomeing increasingly sophisticated and elaborate to offer a better interface and additional functions. However, when we think of the long-term effect of ICT development, the larger framework of the entire process of planning may be affected.

Throughout the last century, urban society and its planning paradigm have been subject to constant changes caused by social, economical, technological, and political factors such as mobilization, economic declines, and the world wars. Yet, we are now faced with another major shift, and the current transition seems to be brought by a combination of several different factors.

From the technological viewpoint, the advancement of ICT, development of telecommunication networks and services in particular, has promoted many social-economic activities in terms of their accessibility and opportunity (Graham and Marvin 1996, 2001, Shiode 2000c). In contrast to motorization that completely altered the urban scene, ICT has merged into the existing urban structure, causing little change on its appearance. Nevertheless, the exponential growth of the Internet and increase in the use of computers cast significant effects on various urban activities (Klabbers 1999). In the field of urban planning, in particular, it promotes the development of supportive tools such as network-based GIS as well as online public participation program and other types of groupware (Mitchell 2002). These technologies are expected to contribute towards automation of the data handling process, reduction of planning time, and increase in the opportunity for public participation (Batty 1996, Geertman 1997, MacEachren and Brewer 2004).

The social aspect, on the other hand, saw that increase in the diversity of life style and sense of values required more flexible planning scheme than that based on rational standards (Sandercock 1998). This includes provision of a feasible solution to the mixed culture of highly-concentrated modern society as well as spatial distortion caused by the development of transportation and information networks, which also relates to ICT deployment in various aspects. In fact, as the digital technology rapidly prevails among the urban space, it raises a social problem called "digital divide" between the information rich—people who have access to ICT resources—and those who have not (Kitchin 1998, Wilson and Corey 2000).

Development of *e*-commerce—a platform to conduct business electronically—has drastically remapped the corporate and consumer's market, despite its recent emergence (Wilson 2000a). Indeed, the latest figures from the U.S. Census Bureau (2005) confirms that, in the 4th quarter of year 2004, *e*-commerce-based activities were estimated at $21.4 billion, or 2.2% of the total U.S. Retail sales ($987.6 billion).

The growth of information space also brings various social issues that were previously unseen; for instance: How do the conventional retailers compete with electronic markets? Should *e*-commerce remain tax exempt? To what extent can we and should we protect our own privacy? How do we restrict minors from accessing inappropriate contents? The list goes on. The information spaces have indeed come to form a topical subject that require planning and management themselves (Batty and Barr 1994, Mitchell 1999).

These phenomena indicate that, among various other factors, ICT plays an important part in the recent shift both directly and indirectly (Mitchell 2002). Some of the issues to be addressed by urban planners in particular then—and the focal points of this section—are the following: How does it affect the urban structure? What impact does it cast upon urban planning? Would it simply provide convenient tools, or is there more to it? In what ways can urban planners contribute to improving cyberspace?

Based on the assumption that the current transition owes much to the rapid deployment of ICT, this section investigates the interaction between urban planning and the growth of information spaces with a focus on the reciprocal impact from the both side to the other. Section 5.3.2 sets the context by reviewing the trend of ICT development with an emphasis on that of various information spaces that form a new objective for urban planning. The interactive factors between information space and urban planning are then categorised into four different groups and interpreted accordingly (Section 5.3.3). We argue that the development of ICT and diffusion of the Internet may bring a turning point possibly as significant as that caused by the Industrial Revolution—in fact, it is occasionally referred to as the digital revolution (Harris 1994, De Mul 1999, Mitchell 2002). In one sense, ICT deployment distorts the notion of spatial order and may even overhaul our standard of values (Healey 1996, Wilson 2000b, Cairncross 2001). We conclude by discussing its impacts and propose a framework for planning process that may better correspond to the transition of the spatial order and the new planning objects of information spaces.

5.3.2 Interactions between Information Technology and Urban Planning

Despite the short history of ICT, computers have assisted urban planning and urban management processes for over three decades (Mitchell 1995). Contrary to some earlier predictions, ICT and the Internet offered few perfect solutions to our social-economic activities in the sense that a perfectly fail-safe system is not accomplished and that a face-to-face contact still maintains priority to virtual meeting (Jones 1998). Also, they are unlikely to replace the conventional technologies and skills (Batty 1993).

In fact, ICT can be regarded as new technologies and media that complement the existing components of cities and, to some extent, reflect the current social conditions where it adds another dimension to our planning scene. Web space and cyber cities, for instance, consist of a collection of electronic data that offers certain degree of spatial awareness and, hence, never replace the entity. However, it would most certainly support the real space by providing functions that would be otherwise time and cost consuming. In fact, we have seen some of such applications in Chapter 4.

While ICT offers useful tools for planning, some aspects of ICT are dependent on urban planning. In other words, general methods developed in the planning field are potentially applicable to the planning and designing of various types of spaces mentioned earlier.

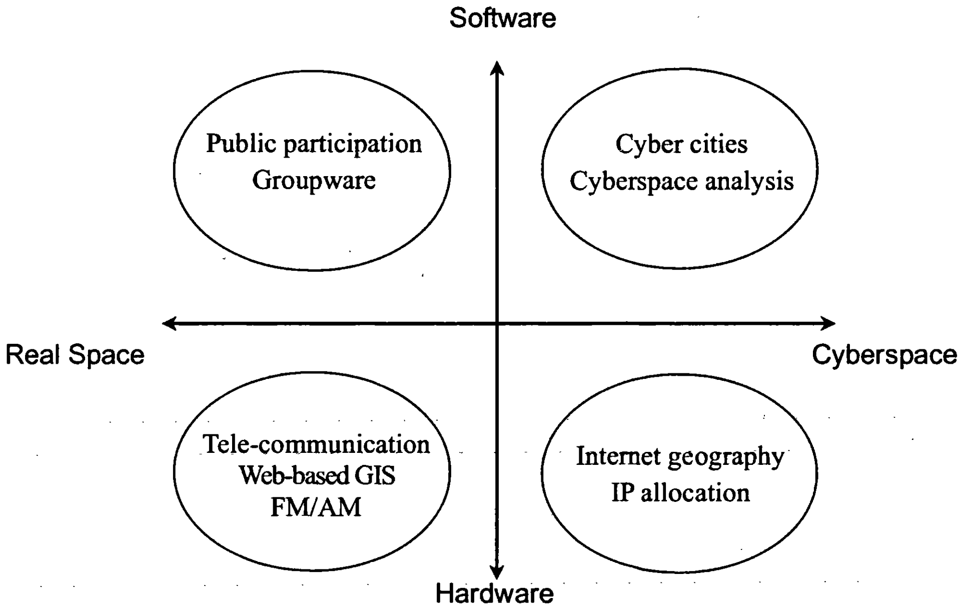


Figure 5.3.1 Interaction between ICT and planning (Shiode 2001).

In essence, urban planning shares the following interdependent aspects with ICT (Shiode 1997):

(a) Information space as a medium to support urban planning of the real world, and
(b) Planning methods applied to the designing of information spaces.

Also, as discussed in Chapter 2, Kaneyasu (1997) defined the contemporary urban environments as "media cities" and classified them by their relevance to ICT as (a) cyberspace: a city within the media, (b) support system: a city supported by the media, and (c) ubiquitous structure: a city containing the media.

ICT deployment is indeed affecting the planning domain both in the physical world and the virtual world. It also seems to have influence on both the application and event-oriented side, as well as on the infrastructure and facility management.

Figure 5.3.1 (same as Figure 2.1.1) summarises the interaction between ICT and urban planning. The vertical axis represents the type of planning contents. On one end is the physical investment and maintenance of hardware infrastructure; while on the other end lies the event-oriented applications. The horizontal axis represents the nature of each space shifting from the solid, physical space of the existing cities onto a more flexible, metaphorical space within the information network, which we discussed earlier.

Depending on their contents and spatial characteristics, the interactive factors fall into one of the four domains. Some elements bear ambivalent nature and may belong to more than one category, whereupon their key function is prioritised. In the following, we will elaborate on these distinctions and explore each of the four categories.

5.3.3 ICT Assisting the Hardware of the Real Space

Establishment and maintenance of urban facilities such as drainage systems and telecommunication network play critical role in providing urban public services. ICT offers significant contribution in assisting such systems and services. Facility management and automated mapping (FM/AM) system, for instance, administrates public services such as waterworks, drainage, gas and electricity through digital information maps. It requires the initial investment in hardware installation and digitization of the source data, but once completed, FM/AM proves to be more efficient, economic and reliable than a traditional administration system used to be (Okabe 1998).

Another utility is a Web-based GIS or Internet GIS; a system that supports data-sharing as well as joint task operation and provides the basic utility of GIS over the network. Although still in its exploratory stage, Internet GIS technology is potentially useful and important for supporting urban planning and urban management, distributing information and providing online geographic data services (Ranzinger and Gleixner 1997). Openshaw (Openshaw *et al.* 1999) operates their GIS tool, GAM (Geographical Analysis Machine), on the Web which provides a platform independent environment and comprehensive interface. A geographic processing system of this kind would be especially beneficial to planners and engineers who need in-depth geographical data of a particular area without investing for a high-end GIS.

Also, an online asset management and administration system that reflects the real-time land use and ownership information is particularly useful in planning urban land use. They are increasingly adopted by the local government level throughout the world (Zhen 2000). Many systems restrict access from the general public for privacy reasons; however, it provides an efficient planning environment for the planners and policy makers.

Data consistency and accuracy is vital for successful operation of these management systems. For instance, the current geodetic reference framework of Japan is based on an internal reference system established in the 19th century. Their co-ordinates are different from the international standard ITRF94 (International Terrestrial Reference Frame 1994), and there is a large discrepancy between the two reference systems. As such, the Japanese government has recently completed an initiative called JGD2000 (Japanese Geodetic Datum 2000) to measure every geographic spot within its territory by ITRF standard (Murakami and Ogi 1999). Here, too, does ICT provide efficient means of measuring the geodetic references through several different technologies such as satellite laser ranging, global positioning system, and VLBI (Very Long Baseline Interferometry).

Consistency of data format is also crucial when sharing data among different institutes and providing them as public domain. For this purpose, the International Standardization Organization (ISO/TC211) is currently setting a standard for meta-data, or the data that represent a set of data through their attributes. Establishment of a well-maintained data clearinghouse is also important (Geertman 1997, Kaneyasu 1997). A clearinghouse refers to a central data-processing server that administrates the information network and enables reciprocal use of data between different organizations. In the case of the United States, it was first established in an NSDI (National Spatial Data Infrastructure) project to provide data that follow the standard meta-data format set by FGDC (Federal Geographic Data Committee).

Other computer supported systems within this category include air traffic control, road congestion monitoring system, or more generally, tele-geomonitoring and geo-processing utilities. Although each system depend on their own infrastructure, the information obtained from the systems are fundamentally universal, and there is a constant demand for integrating their data structure with one another to build a synthetic, computer-supported maintenance system so as to administrate all systems from a few support centres linked by the computer network (Laurini 2000).

5.3.4 ICT Assisting the Software of the Real Space

The second category features applications that support planning and designing for the real cities. Many planning support schemes have been proposed in the past, ranging from a straightforward linear process to knowledge-based models. However, majority of them has been targeted at a small group of professional planners working in the same space at the same time. The computer network resource provides new possibilities for various network-based planning support systems. They aim to offer a collaborative working environment as well as to implement online public participation tools through various applications and are expected to become a major means for providing information to the public as well as receiving their feedback (Shiffer 1995, Patterson *et al.* 1996).

Groupware is one of the options that assist the users to collaborate in such planning process. A collaborative task is jointly carried out by multiple participants, which would fall into one of the four categories of time-space matrix shown in **Table 5.3.1** (Dix *et al.* 1998).

Table 5.3.1. Time-space matrix.

	Same place (local contact)	Different place (remote communication)
Same time (Synchronous)	Face-to-face interaction, Public meeting	Telephone, Tele-video-conference, Groupware
Different time (Asynchronous)	Post-it note, Sequential and accumulative tasks	E-mail, News, FAX, Web-based distribution

Participants are usually assembled in one place at the same time when holding a conventional meeting for a face-to-face contact. Groupware enables its users to login from different locations and interact with each other in the virtual environment. The system is usually called either CVE (Collaborative Virtual Environments) or CSCW (Computer Supported Collaborative Works). The goal of CVE projects is to provide a 3D, multi-user space for planning and designing process. Among the projects recently developed are MASSIVE (Model, Architecture and System for Spatial Interaction in Virtual Environment) by University of Nottingham (*www.crg.cs.nott.ac.uk/ research/systems/MASSIVE-2/*) and DIVE (The Distributed Interactive Virtual Environments) by the Swedish Institute of Lennart Fahlen (*www.sics.se/dive/dive.html*). CSCWs are aimed at more general, decision support system including protocols such as NSTP proposed by Lotus Inc. and conceptual model such as Meta-Web by GMD Co. The systems are yet to be developed for a full-featured urban planning support system (Jones 1998).

In contrast to the comprehensive planning support systems, there are some frameworks that serve for specific purposes. While their uses are rather limited, these purpose-built systems are much easier to construct and implement because of the clear vision of their purposes, and in fact, are increasingly being adopted by some decision-makers and local governments. Examples include a multi-user argumental map application that used in an online, 3D, multi-user planning scene (Rinner 1999) and an online public hearing system that enables the feedback on master planning (Kobayashi and Hibata 2002); which are collectively known as *e*-Governance.

5.3.5 Urban Planning Assisting the Hardware of Cyberspace

The third category focuses on the physical aspects of ICT planning; that is, locational planning and geographical analysis of the physical side of computer networks. Although the structuring of the Internet involves some critical problems and requires proper planning and analysis, relatively few have seen this area from the planning perspective (Batty and Barr 1994, Graham 1997). Among few exceptions is the case study discussed in Section 2.2, which analysed them from a geographical perspective (Shiode and Dodge 1999a).

The high demand for Internet services and congestion urges further infrastructure deployment. Investment in broadband capacity by the public and commercial service providers may not necessarily improve the condition, as it may stimulate further demand and, hence, more congestion. Careful traffic management and allocation planning are essential to utilize network resource effectively.

Components of the Internet are scattered over the world, but the Internet itself is regarded as a single network — an electronic compound dynamically growing and changing. Therefore, administration and management of the Internet need to take two different approaches. Distribution pattern of its elements (e.g. the location of server machines) can be analyzed using the conventional methods developed for facility management, whereas the structure between various cables and satellites should be treated as a network-flow problem. As information network is an integral part of social and economic development, spatial analysis and locational optimisation of Internet structure will come to form an essential part of urban planning when incorporating it to the existing urban structure.

5.3.6 Urban Planning Assisting the Software of Cyberspace

While its definition is still ambiguous, information space potentially forms a new planning domain for urban planning (Batty 1993). This is especially so, when we interpret it as a complementary living environment for our intellectual, social and economic activities to which urban planners can provide valuable advice and guidelines for its usage (Shiode 2000c).

In certain respect, urban planners may contribute their knowledge in planning various cyber cities and cyber-places. Again, there is no clear definition of what a cyber city is, and the range of information spaces that have been studied and discussed throughout this thesis are still not widely considered as geographic entity that can be subject to spatial planning (Shiode 1997). Nevertheless, 3D virtual worlds holding a large number of users are gradually being developed, many of which supporting interactive, multi-user environments. We have seen an example of such effort in Section 5.2.

Unlike the real cities, cyber cities are easily built and electronically maintained within a server, and users can enter them via computer network. Apart from the running cost of the server, it is virtually free from financial constraints. However, a new price system for the land value of "cyber estates" is emerging; they are dependent on their topological position in relation to the major portal sites. A site or location with heavy network traffic is considered to be potentially valuable for marketing reasons.

Once a new cyber city emerges, it develops much faster than a real city, growing almost evenly to all directions at the centre and continuously sprawling outwards. We saw an example of such study earlier (Section 3.2.4) where the growth rate of AlphaWorld was measured by way of applying fractal analysis. The study reveals that the city has developed remarkably within a 14-month period and is now as dense as Manhattan in terms of the flat-area-coverage rate. Practically no planning regulations or rules are applied in these spaces and consequently, the overall impression of these cyber cities is chaotic and confusing, not to mention the aesthetics. It would be useful to provide guidelines from the urban planning perspective for constructing a cyber city with clear and clean structure.

On a more abstract level, yet perhaps more relevant to the real urban environment, is the planning and policy making of various commercial spaces including those of *e*-commerce and other Web sites in general. The growing revenue of *e*-commerce or cyber-malls has raised a huge debate on whether or not they should remain tax exempt which still remains unresolved. Another field that marked a rapid growth is Web address trading. A popular domain name such as "business.com" are put on bids and itself generates a large amount of money without any actual implications of matching benefit. Pursuit of domain names also attracted "*cyber-squatters*" who obtain certain domain names that remind of a specific organization to which they sell the domain for an outrageous price later on. These activities are currently restricted in the U.S. but are still not interfered in many other countries.

There are several other issues including protection of privacy as well as accessibility to inappropriate contents, whether for its indecency or political nature. Because the very nature of the Internet rejects enforcement of authoritative power from any single sovereignty, it suffers from lack of appropriate protocols to be reflected.

While it is difficult to judge the ethics of what should be allowed and what should to be banned, planners may need to provide certain framework for a universal guideline. This is even more so in the light of recent emergence of ubiquitous network society, where seamless access to information space is imminent. Naturally, the traditional urban planning methods cannot be applied to this unconventional and dynamic object; however, there are some implicit rules being formed as "netiquette" on top of which we may comprise a guideline.

5.3.7 Urban Planning of the Internet Era

We have seen that urban planning is related to ICT in various ways and that the degree of their interdependence is growing stronger. It is also clear that the notion of space and information have been largely modified by digitisation and the deployment of computer networks which in turn, will reform urban planning itself. Various other social and geographic factors are also urging the shift of urban environment.

What, then, would come out of this interaction? What planning scheme should we adopt to correspond to these changes, especially those led by ICT deployment? In what manner could we actually utilise ICT to benefit from its computational capacity and communication technologies? The next section describes one possible direction for the next generation of planning scheme.

Diversity amongst the Planning Objects

Let us go back to the interaction diagram shown in Figure 5.3.1 for a moment. We observed an increase in the numbers and types of planning objects; especially those associated with the newly emerged cyberspace. In addition to the spatial and contextual criteria that divided the planning objects, we also have, as seen in Table 5.3.1, the temporal dimension that determines the synchronicity of events. If we were to provide a planning scheme for all such objects, we should reconsider the framework of the current urban planning from these three aspects.

While it is difficult to depict the exact image of the future paradigm under the rapidly changing socio-economic conditions, we should aim at a flexible planning scheme, laying more emphasis on the process rather than adhering to the final output which has been the case in some of the conventional planning schemes. The new paradigm should thus address various objects that have different values for various criteria including the following three

1. Physical accessibility (distance metrics): real space - cyberspace
2. Chronological order (time scale): synchronous - asynchronous
3. Contents attribute (component category): hardware - software.

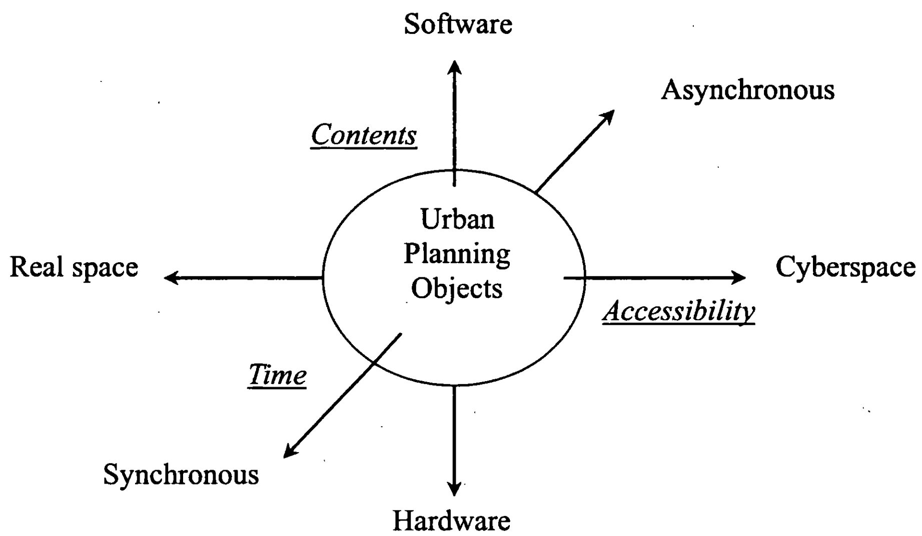


Figure 5.3.2 A schematic diagram on the directions and factors associated with urban planning (Shiode 2000c).

The attributes are displayed in the spatio-temporal diagram in Figure 5.3.2 where the three axes determine the nature of each functional space and classify the planning objects accordingly. The distance axis reflects the order of accessibility, not necessarily in the local-remote scale of spatio-temporal matrix, but with a range of spatial attributes from the ordinary Euclidean metric space to a topological hyperlink space.

Time axis refers to the synchronicity of the planning applications, ranging from a simultaneous co-operative task to a sequential, multiple processes. The third axis indicates the type of contents that ranges from hardware management such as infrastructure administration to software planning such as cyberspace usage guidelines.

The Shrinking Society and Its Spatial Reconfiguration

Despite the geographical and political boundaries of nations and cities, development of transportation and communication networks has improved the accessibility across the borders and continents (Mitchell 1995). As the travelling time is shortened, more population and resources cross between different regions at an increasing rate which encourages sub-urbanization and cross-cultural exchange (Sandercock 1998).

The infiltration of heterogeneous global culture has changed the nature of spatial order between and within the global cities, and the traditional, unique characteristics of each city have been affected by the cosmopolitan culture. ICT deployment pushes this even further; it connects most of the global cities through communication network and builds virtually a single structure.

Cairncross (2001) predicts that when the information network is fully developed and cities form a fully-wired network society (ubiquitous network), the boundary between urban space and information space would cease to exist. While this vision of seamless info-society still appears somewhat farfetched, it is perhaps reasonable to assume that majority of urban population will be likely to lead a duplicate urban life in the real space as well as in cyberspace in the near future.

ICT deployment directly affects the following aspects of network societies:

1. Spatial order and accessibility to different locations
2. Real-time information sharing and urban economic activities
3. Diversity of life style and opportunities in urban amenity space
4. Evolution of cyberspace as an alternative living environment.

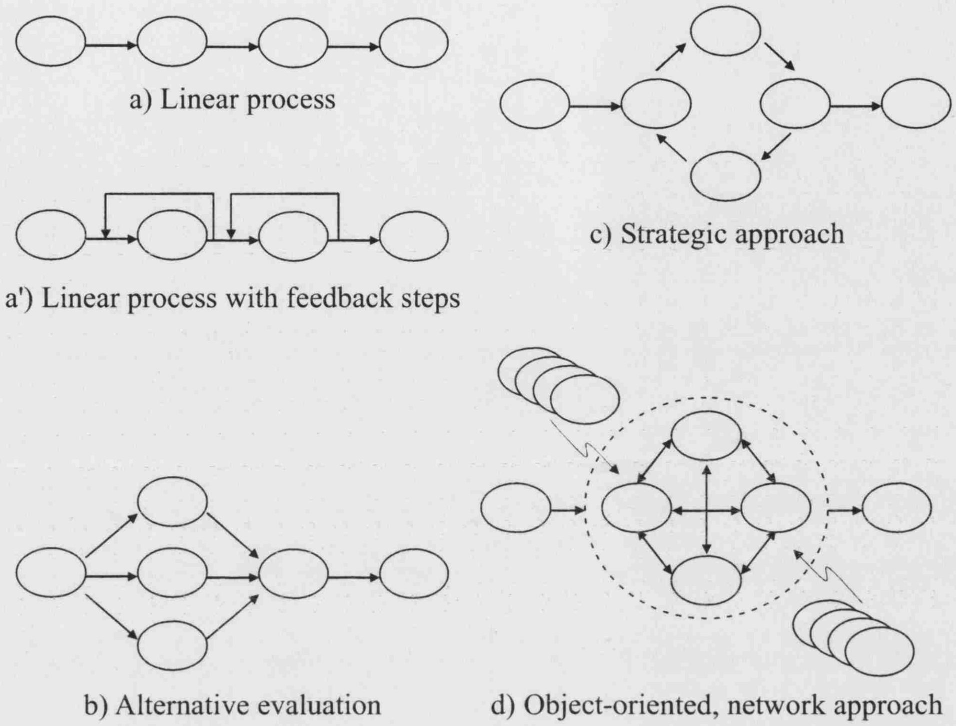


Figure 5.3.3 A schematic diagram of flows of the planning process: (a) linear process, (b) alternative evaluation process, (c) strategic approach, and (d) object-oriented approach (Shiode 2000c).

Despite these changes, the physical structure of the existing cities has hardly changed. The discrepancy between the "vessel" and its "contents" seems to invite unnecessary conflict and crime. The new planning paradigm should be flexible enough to correspond to different cultures as well as various spatial orders in the network society.

Object-oriented Planning Framework

What framework would tolerate such diverse planning objects? A number of schemes have been applied to the planning and decision making processes in the past (Figure 5.3.3). The most conventional method is the linear process (also known as the *tandem process*) where the planning issue is raised in the first instance, to which a solution is proposed and then implemented; to be followed by the assessment. Introducing feedback processes makes it slightly more sophisticated. The alternative evaluation structure is a variation of the linear process except that it enables its users to compare different options. However, all these schemes require long planning period. Other approach includes the strategic scheme where each tactics or solution is formed through a recursive brainstorming and feedback process. Yet this approach, too, supports only the fixed, anticipated options and objects.

In order to cover the different planning objects, we may need to abandon any planning scheme based on a rigid structure and adopt a dynamic and individualistic planning approach instead. Some of the recent planning support systems employ the idea of knowledge-based, expert systems (Marquez and Maheepala 1996, Yeh and Shi 1999). In terms of the software architecture, these applications still belong to the group of post-spread-sheet or the custom written software (Klosterman 1998). In other words, these models are mostly designed for a specific planning or decision-making purpose, as the basis of knowledge for a wide-range solid expert system was difficult to be fixed. Nevertheless, if we leave the structure of the planning system largely flexible and apply the idea of a dynamic, object-oriented scheme, the entire system would function as a reference system, an open framework that provides guidelines and place for interactive discussion; and, as we keep accumulating the previous cases, it would become more and more useful.

In terms of object-oriented paradigm, a few planning applications were developed in the 1990s in the fields of artificial intelligence and computer programming; namely, Excalibur (Drabble 1995), NPNB (ICS 1996) and I-X (Tate 1999). These studies aim to link the hierarchical planning schemes with the attribute representation of the planning object so as to resolve real-life problems. Many are intended to provide intelligent workflow for specific business process management, but the basic concept is applicable to a wider planning domain. Two elements are essential for object-oriented scheme; a sufficient resource for intensive use of information and data exchange, and interactive environment that assists multi-user discussion—both of which are attained by utilising information spaces.

The standard procedure of object-oriented scheme can be formed through the following steps.

1. Extraction: select a set of classes that clearly defines the problem
2. Declaration: identify the components (objects) of each class
3. Definition: establish the links between these classes
4. Application: assign a set of attributes assumed by each class.

Each process will be repeated to maintain the dynamic and interactive nature of the planning process—the diagram shown in Figure 5.3.3(d) represents the kinetic state of the process, rather than the static hierarchical structure observed in a typical object-orientated framework. The object that are dynamically imported and replaced here are supposedly either predefined within the accumulation of previous planning record types or declared as a new planning type at that instance. Again, establishment of class library would require substantial amount of initial investment in terms of expense and labor involved. Once the framework is set up, a list of precedents will be compiled in a relational format that would accommodate the considerable increase in the number of and variation in the types of planning objects in the near future.

In the actual iteration process, we first provide a large set of planning guidelines as a basis of rationale. This set should comprise a number of small elements representing the three different dimensions of the planning objects. For instance, a color scheme guideline may have different attribute sets for the real cities and cyber cities. The scheme itself would be a dynamic, modifiable vessel. Once the planning theme becomes clear, the framework can be tentatively built through linking the component options, as if selecting the right pieces of building blocks to construct a single castle. Components can be removed or added at any stage as appropriate—taking the block analogy further, we may turn to the toy box and pick up any additional piece or put back the redundant pieces as we wish. The class attributes will then be determined; e.g. the color and size of each piece.

In case of planning a cyber city, for instance, the initial framework would consist of Web-market investigation, traffic estimation, link structure layout, cyberspace designing, security management and maintenance. These factors would be further divided into smaller components; and, if some components share a common class property or have the common class declaration type among the library (or the precedents), they can be recycled at different planning stages. Advantages of using object-oriented approach include:

1. Flexible and applicable to a wider range of planning objects
2. New components can be added at any time allowing changes in the objects
3. Public distribution available at each component level
4. Planning process can be easily divided for simpler collaborative tasks
5. Precedents and case studies can be easily quoted and reused.

The disadvantages of such planning scheme are

1. Need to accumulate a number of planning objects to create the library
2. Appropriate components should be selected each time a new project begins
3. An operator is essential for handling various objects and classes in a complex planning scheme.

In fact, as the entire planning process becomes more complicated, we may have to provide a planning tool for designing the layout of the planning scheme. Still, object-oriented paradigm would allow most of the exceptional conditions and enhances individual opinions in short period by adopting the appropriate components, and its basis would quickly become firm and reliable as we start accumulating the case records.

Object-oriented, Multi-user Network Environment

In addition to the discussion of the object-oriented scheme, we should also consider the aspect of multi-user interactivity and public participation as a standard procedure of contemporary planning process. As we saw in Section 5.2, information spaces have the capacity to accommodate this; thus providing an ideal environment to offer both (a) the flexibility of object-oriented framework, and (b) the interactivity among multiple users. This unique combination of flexibility and interactivity is further enhanced by its near-real-time communication and knowledge retreival capability. In other words, the increasing use of ICT in the planning arena suggests its transition towards object-oriented, network approach supported by information space.

Benedikt (1991) suggests that, if we were to look at information space from the conventional planning perspective, we should decompose its structure all the way down to each and single object that forms the space and its links. While it is focused on cyberspace planning, the underlying structure of his proposal can be interpreted as that of an object-oriented scheme with a capacity to cater for multiple users — it is perhaps the only obvious solution to handle the diverse objects and events both from the real and virtual world and carry out a planning action regardless of the geographical location of the colleagues involved.

5.3.8 Summary of Findings on the Transition of Planning Processes

In this section, we reviewed the transition of urban planning that has been brought about with the advancement of information communication technology. The interactive factors between urban planning and ICT were classified into four different groups depending on their nature. In essence, urban planning and ICT were interdependent in the sense that ICT provides technological support to the planning system whereas urban planning can help planning and designing information spaces. We then explored the framework of a new planning scheme, if only hypothetical, in an effort to cover the diversity of planning objects and to correspond to the changes of modern urban society and its spatial order.

Hall (2002) argues that, much similar to modern industrial urban economy, agglomeration still plays a significant role in the information economy. He points out that new-style, highly equipped edge cities such as La Défence in Paris, Canary Wharf in London, Kista in Stockholm and the Amsterdam-Zuid district have come to supplement—or even to supplant—traditional central locations, especially in terms of electronic communication. Their counterparts in the virtual environment are also polarizing and agglomerating to certain portals at a much faster rate (Shiode and Dodge 1999b). These trends imply the demand for the appropriate planning and guiding of their spatial usage, both in the real and virtual worlds.

At the same time, growth of information spaces promotes the use of network-based planning systems that can provide the shared environment for multiple users online. Indeed, development of ICT is a phenomenon prevailing on the global scale. To some extent, it transcends the difference in cultural, regional and economic conditions. The worldwide information and transportation networks bring distant cities closer, distort their spatial orders, generate new form of cities and spaces, and loosely link all the components — that is, for the first time in history, we will have a global conurbation of Ecumenopolis loosely defined on the digital layer. On the other hand, diversity of the planning objects would almost certainly increase, ranging from traffic management to cyberspace designing to Internet geography. In addition to this, we should also remember that deployment of ICT and the digital paradigm is a double-edged sword that may lead us to the trade-off between improvements on some socio-economic activities and the newly emerging social issues such as digital divide and community collapse—which also form planning objectives on its own in this ICT era.

Mitchell (2000) suggests that, in order to build successfully on the digital development, we should reinvent the concepts of urban design and development, and construct an *e*-topia (electronically serviced, globally linked cities). It is a comprehensive form of a favourable future that encompasses the elements much similar to the ones discussed earlier in Chapter 2; i.e. virtual and physical places, software as well as hardware, and inter-connection by means of telecommunications links as well as by physical adjacencies and transportation systems.

Use of the information communication technology for simulating and predicting the future land-use scenarios of an urban environment has become popular in the fields of planning and geography (Graham and Marvin 2001, Brail and Klosterman 2003, Yin 2004). However, the prospect of using information space as a spatial resource for urban growth simulation and dynamic and online, object-oriented planning support system is yet to be fully explored (Shiode 2000c, Torrens 2002, Shiode and Torrens 2003). There is also still much to be explored in terms of the difference in human behaviour in the real and virtual environment (Slater *et al.* 1998, Axelsson *et al.* 2001) and social relations in multi-user VR environment (Schroeder 1999). In that effect, this chapter presented just one possible approach to the application of information space in the planning context, and further research would be required to investigate an effective process and procedure for implementing planning or decision-making activities online.

CHAPTER VI

CONCLUSION

6. CONCLUSION

6.1 Summary of Findings and Contributions

6.1.1 Summary of Findings Obtained in This Study

This study analysed some of the basic spatial characteristics of information spaces and explored online applications in the hope of understanding their spatial structure and identifying an effective way to utilise such spaces. The study focused on offering a geo-morphological interpretation of the various information spaces and the spatial structures they had, rather than understanding the sociological or contextual aspect of these spaces. The underlying assumption was such that information spaces possess spatial properties that are comparable to those of the real world we live in, and that they can be perceived as a measurable, finite, and mappable system subject to geographical and geo-morphological interpretation.

In particular, the first half of the study, through Chapters 1 to 3, consisted of a series of geographical analyses conducted on a variety of information spaces. It started with a revision of the evolutionary process of various information spaces in the last decade (Section 2.1). Four different types of information spaces were identified:

1. The physical infrastructure of the computer network,
2. Topological structure comprising the information space,
3. Pseudo-3D world of invented spaces and cyber cities, and
4. The enhanced reality of the real world with embedded ICTs.

This essentially formed a typology of the information spaces where each category was defined by the difference in the degree of its spatiality but were nonetheless dependent on one another to form the larger structure of the information space as a whole (Figure 2.1.2) (Shiode 2000c). In order to understand the spatial characteristics of each information space, a sample set from each of the first three categories was examined in the form of case studies in which they were visualised and compared to their counterpart in the real world from a geographical perspective (Sections 2.2 ~ 2.4). The underlying assumption was that these spaces, despite the lack of their physical entity, had a certain degree of spatial-awareness that could be regarded as a subject for geographical analysis (Shiode 2003).

Deriving from the comparison on the real and virtual worlds at the structural level, a hypothetical model was constructed in Chapter 3 where the growth of the range of information spaces was simulated and compared to those in the real world. The objectives of proposing a method to interpret and model the geographical features of information spaces were achieved through the adoption of an astro-physical model that was fitted against the scaling tendency of distributions in these spaces. The scaling distribution of the size of sub-spaces and elements within each type of information space suggested that these spaces are still in their evolutionary stage and have yet to mature as a system (Batty and Shiode 2003). It was also inferred that their remarkable growth rate exceeds that of most social-economic systems and was indeed comparable to that of the constellation systems and the expansion of the universe. We should note, however, that Hannemyr's study (2003) suggests that many new media and devices had a similarly remarkable growth rate of uptakes by the users when they were first introduced. In other words, as far as the number of users was concerned, the popularity of other inventions (e.g. television, phone, radio) increased initially at a comparable scale, despite our popular belief on the unprecedented rate of growth by the Internet. Nevertheless, what we studied here was the growth and development in the spatial extent of various information spaces, which has been evolving at a different level.

A particular focus was set on the ways to interpret the geography of information space. We have tried to understand the similarity and the difference in spatial attributes observed among the range of information spaces, and between the real and the virtual world. Although they were conducted in an exploratory manner, they helped to depict a picture of the structural layout and the growth dynamics of the various information spaces. The study also employed the method of analysing the scaling distribution in the attempt to model their geo-morphological characteristics. From what we observed, we can conclude that each category of information space is rapidly expanding in its size as well as the number of its elements, despite that each has a distinctively different notion of distance and adjacency to the neighbours and its immediate vicinity.

Based on these analytical insights, the latter half of the study explored the ways to utilise the dynamic and flexible nature of information spaces through a series of case studies (Chapters 4 and 5). They consisted of a series of case studies carried out for the purpose of accommodating (a) dynamic productions of customised VR space (Section 4.1), (b) the exploration of the electronic interactivity for aesthetic approach (Section 4.2), (c) virtual reproduction of historic landscapes with 3D models (Section 4.3), and (d) designing and implementing an online decision support system (Sections 5.1, 5.2). The main objectives shared by these case studies were to examine the usefulness of information spaces as a complementary facility to the real space. Each case study helped us gain insights on different style of information space utilisation. The fact that we can modify the attributes and features of elements in these spaces and also interact with the environment as well as other users makes the potential range of its application almost endless.

6.1.2 Contributions of This Study

Although this study is confined to the quantitative and structural understanding and exploration of information spaces, the insights and implications obtained through this study are diverse and significant in many respects. In particular, the following achievements were established:

(a) this study laid a foundation for the typology of the range of information spaces from geographical and spatial perspective,

(b) this study proposed innovative ways to utilise the spatial characteristics of information spaces to help enrich our aesthetic, cultural, and planning experiences by actually exploiting the flexibility in their geo-morphological structure.

Geography and Typology of Information Spaces

Identification of different types of space, supported by a series of empirical case studies on a subset of each type of information space, is a unique task in itself. It clearly illustrates the difference in their structure and the spatial order, which have not been previously pursued (Shiode 2003).

The insights obtained from the categorisation effort may be particularly useful for those who are trying to identify the complexity of information space and their growth. Rather than providing the exact statistics, or the accurate picture of the ever-changing Internet, this study focused on making an empirical contribution towards the understanding of its geography, through observing the distribution pattern and the characteristics demonstrated by a subset of each space type, and comparing them to one another. It also made notable contribution towards the planning of an efficient and effective use of information space, which would help to improve our understanding of how their categories can be set, how they relate to each other, and also, how they are associated with the real world.

Utilisation of the Dynamic and Flexible Nature of Information Spaces

The latter half of the study looked into a range of different applications. They made a breakthrough in identifying and actually carrying out preliminary case studies on such applications that were previously not widely known. This is not to say that similar case studies and experiments have not been carried out before. For instance, Schroeder (1996) provides a comprehensive account of the technological and sociological implications of the use of VR technologies in his pioneering work, *Possible Worlds*. Several other studies have been also conducted to confirm the effectiveness of the use of information spaces (Graham and Marvin 1999, Hudson-Smith 2002, Schroeder 2002, Takeyama 2003).

However, much of these efforts were targeted at contextualising their sociological aspect; whereas the purpose of my study has been focused on utilising the flexible and dynamic nature of information spaces. In this respect, the case studies featured in Chapters 4~5 have successfully demonstrated the effectiveness of using information space as a supporting and complementing medium for the real world—that is, if the case studies were limited to the specific contexts of art, culture and planning. The series of case studies have indeed opened a path for dynamic experience of spaces such as those in enriched aesthetic experience, and real-time, online multi-user planning. The flexibility found in the spatial dynamics of information spaces is a truly unique aspect and should be utilised for enhancing our social-economic activities. The case studies were successfully carried out to help demonstrating and emphasising this point. They also helped us gain knowledge on the issues and possible problems against using information spaces for such applications.

6.1.3 Issues Left for Future Research Directions

The series of analyses and case studies conducted in this thesis are timely and are believed to make unique contributions to the emerging field of information geography. They also cover a wide range of topics, if at the cost of sparing in-depth analysis on each topic. In other words, much of the analysis and case studies carried out in this study are of exploratory nature and are by no means comprehensive; they would certainly benefit from further research. Here are several possible research directions that would emphasise and strengthen the studies that I carried out so far.

Calibration and Experiments

Perhaps the most apparent shortfall of this thesis is lack of comprehensive experiments and tests that support the validity of the proposals and applications suggested in this study. For instance, aside from the analytical insights obtained in Chapter 2, the scaling model proposed in Chapter 3 is not tested against any real data.

This is also true to some extent with the range of applications discussed in Chapters 4 and 5, where context-specific case studies were conducted but they nonetheless failed to assure that such style of utilisation would be applicable in a generic manner, independent of the aesthetic, cultural, or the planning context under which they were tested.

As the primary purpose of this study was to categorise and showcase the range of information spaces and to demonstrate possible applications that utilise such flexible spaces, calibration of the real data was beyond its scope. However, it forms the crucial next avenue of my research to evaluate the proposed models. For instance, the author is currently planning on carrying out further research on the comparative analysis of real and virtual cities to follow up on the results presented in Section 2.4 (Shiode and Torrens 2003).

Geo-visualisation

Although most of the applications discussed in Chapters 4 and 5 involved some degree of visualisation and aesthetic elements, representation of the analytical results was not examined in its full detail. In particular, the geo-visual representation of the subsets of information spaces discussed in Chapters 2 and 3 was achieved by adopting arbitrary method of illustrating the results, where the efficiency and the effectiveness of such representation was not given the highest priority.

As Dodge and Kitchin (2000) showcase in their recent publication, there are host of examples on visually appealing and persuasive way of presenting spatial distribution of datasets that do not correspond to the positioning of the conventional geography. The art of selecting an appropriate cartographic scheme for visualising a real-world geography has been studied for centuries now (Slocum *et al.* 2005), but we will need to revise geovisualisation methods to correspond to the emerging virtual geography of information spaces (Fabrikant and Skupin 2005). It will help to improve the visibility of the results obtained in the likes of the case studies described in this study and, therefore, would be a valuable component of future development in the field of information geography.

Spatial-temporal Analysis

With the exception of the comparative study on the real and virtual cities (Section 2.4), most analyses in this study were conducted at a single time point; hence capturing only a snapshot of their state. As information spaces continue to expand and evolve, we will need a time-series analysis that follows the growth of each type of space and transitions amongst the range of spaces. In particular, the comparative analysis of spatial-temporal data from multiple time points would help us gain better insights on the extent of their growth and enable us to give a more reliable prediction on the trajectory of their future growth. As discussed in Section 1.2, there are several organisations that specialise in collecting survey data at a specific interval. Depending on the level of details of their data, they could be utilised as the basis for the spatial-temporal analysis on the growth of information spaces over time.

Cognitive Science and the Human Interface

This thesis included little discussion on the cognitive aspect of information spaces and their impact on our degree of spatial awareness in the information spaces. For instance, why do we find information "on" a website but "in" a cyber city? If we are surfing backwards from one web page to its preceding page through the Web browser, do we go "back" to the "next page"? What constitutes the "starting" point, or the point of reference for a virtual trip in an information space? These questions would also relate to the issue of navigability and interactivity of such environments.

In order to provide a fuller understanding of the spatiality of information spaces, we will need to conduct experiments on the environmental behavioural aspect of these spaces. A good example of such survey has been presented in Section 4.3 where participants of a workshop were asked to navigate through the online archaeological resource to test its operability and navigability. By organising a similar type of user-group surveys, we may be able to improve the human interface of applications such as those described in Chapters 4 and 5. Similarly, comparative studies on the way users perceive and behave in real and virtual spaces would improve our understanding of the environmental behavioural aspect of information spaces. The difference in the degree of spatial awareness we have for the real world and for the virtual world would also become an essential element for planning information space applications and trying to utilise the spatial flexibility of information space.

Variation in the Range of Information Spaces

Finally, the four categories of information spaces proposed in Chapter 2 were formulated around their current range. As ICTs are likely to keep growing and help further evolution of information spaces, the number and the categories of information spaces may change over time. However, the brief history of information spaces suggests that these changes will likely yield additional spatial categories amongst the existing range, rather than replacing them. In this respect, the sequence of spaces illustrated in Figure 2.1.3 will not only present the current range of spaces, but can be thought of as a base map for the further development of information spaces that lies ahead of us. In the next section, we will observe the current development of ubiquitous network-based spaces and society as a sign of further evolution of information space.

6.2 Where Do We Go from Here?

Divergence of Infor- mation Spaces and Rise of Ubiquitous Network Society

6.2.1 Divergence of Information Spaces

All the information spaces identified in this study are continuously developing at a rapid speed, and they are becoming increasingly complex in their structure as they absorb more resources and information. This includes the significant increase in the amount of online, social-economic activities that takes place in these spaces as well as the number of users involved. It is likely that, in the very near future, a large part of urban population will be using the information spaces through a variety of modes, consciously or not. For instance, in order to retrieve information and to reflect their opinions, we will increasingly depend on the information services provided through the Web, online newsgroups, video conferences, and whatever information space that follows the current range. In addition, a large number of commercial firms and industries, including the stock trades and bookstores, will strive for a competitive position in the new trading zone of e-commerce as information spaces continue to attract more users (Mitchell 2003, Laudon and Traver 2004).

As Kitchin (1998, p.159) points out, "*clearly, cyberspatial technologies are leading to rapid globalisation but within this global economy there is much activity and restructuring as places seek to gain competitive advantage.*" Other people such as McCollough (2004) suggests that a "*decade ago, some people expected those fields (in planning and architecture) to converge into something called cyberspace. Today, hardly anyone seems content with that notion. For me, and not me alone, part of the change has been a turn from the fast and far-reaching to the close and slow. [...] Few of topple our viewpoints voluntarily, without a catalyst. For me, and for this book, that catalyst has been pervasive computing. This expression represents a paradigm shift from building virtual worlds toward embedding information technology into ambient social complexities of the physical world.*" What we are witnessing is essentially an uneven, asymmetric process of multi-polarisation rather than decentralisation, more complication than simplification, and more and more seamless and pervasive network computing environment.

Replacing some copper wire with fibre optics and launching more commercial satellites may improve the performance of data transmission for a while, but it will not be sufficient for keeping up with the rapid growth of information spaces. In fact, the information spaces are already growing into a massive, disorderly arrangement that requires roadmaps and directions to navigate and utilise (Sørensen *et al.* 2001). If we abide by the present principle of *laissez-faire*, the Internet and its variations-to-come would eventually form a massive labyrinth of miscellaneous data to which we would be forced to adjust ourselves in exchange for the information dependent urban lives.

How could we get round this? And what is to come of the information spaces? What alternatives do we have for the future development of information space? How could we benefit from the use of the information space and yet maintain the quality of its service, if the space itself were to grow so fast and complex?

Rapid development of information space will soon yield answers to these questions one way or the other. Unfortunately, it does not look entirely promising, if not devastating, from where we stand now. We have seen earlier that we are unlikely to overcome this speed of evolution or actively determine its direction; and, because it develops at such a remarkable growth rate, we have few effective means to restructure or reorganise the current information space but, by and large, would have to accept it as it is.

There are two immediate consequences of this information-space evolution. One prediction is that, rather than trying to revamp the structure of the existing information spaces, we may start using different modes and alternative information spaces to obtain better service. For instance, as of today, some institutes are already experimenting on Internet2, a computer network 45,000 times faster than the best telephone modems we use to reach the present Internet (UCAID 2000). At the moment, access is limited to registered academics only, but the fundamental technologies would be adopted by the participating industries, and there will be a fully commercial equivalent expected before long. In this manner, the new information spaces will soon come into existence and each space would have different functions assigned to it. This obviously does not provide the ultimate solution for the construction of a clear and comprehensive information space — as history may well repeat itself, and these alternative spaces could grow exactly in the same manner.

The other direction of evolution relates to the deployment of information hardware or the portal device for accessing the information space. Beside the diffusion of the conventional desktop and mobile PCs, there are currently other types of means and devices for information service that are gradually being developed and distributed. These include interactive cable televisions, online game equipment, and various handheld and wearable mobile communication tools. Once these tools become sufficiently available, information space may become more accessible than it is now, and would eventually evolve to an alternative dimension of our lives that is near-instantaneously accessible to the users regardless of their actual location; and perhaps continuously accessed by those who choose to simultaneously live the dual life in the real and virtual worlds. For instance, seamless access to the information network would become particularly useful in business scenes where professionals could appreciate the spatial-temporal flexibility of such new work environment (Sørensen and Gibson 2004).

6.2.2 Ubiquitous Network Society

The above scenario discussed in Section 6.2.1 may sound like a scene from a science fiction movie, but when we think of the prevailing mobile-phone culture and the probable consequence of the emergence of the wireless-based information spaces, it may not be too far from the truth. The widespread availability of broadband network is becoming increasingly imminent in the developed world, covering a larger area to provide better online accessibility and opportunity. The notion of distance is drastically changing in that (1) we can interact and trade with people in a geographically distant location through ICT (information and communications technologies) networks (Wilson and Corey 2000) and, more importantly, (2) it has improved our ability to access and utilise information to the extent where we have near-continuous access to the information network. Some societies are fast approaching the state of ubiquitous, seamlessly wired community (Laurini 2000, Shiode 2004).

As discussed in Section 1.2.3 on Weiser's (1993) analogy of information "waves," we are likely to go through the fourth wave of computing where many people will come to share many computers as well as the data and information within. This has a significant impact on our social and economic activities in general, as the extent and the amount of information we can access and control will become enormous. Furthermore, it enables us to gain access to a large database of information from anywhere and at anytime so that we can monitor, control and operate events online whenever necessary. Sørensen and Gibson (2004) point out that this, however, is achieved with the cost of the constant attention through the information network.

Also, to achieve such seamless network of ICT environment requires a lot more than simply installing computers. It requires (1) computers and microchips to be embedded in everything that needs to be connected and accessed that range from PCs and PDAs to home appliances and road-side appliances, (2) various channels of ICT networks such as ASDL, wireless LAN and the 3rd and the 4th generations of mobile telecommunication to be integrated within the entire framework, and (3) development of a standard protocol that acknowledges and helps the communication between the wide range of IC products. In addition, we will be forced to revisit practically all the social and technological issues such as the protection of privacy, digital divide and online security over the network, as these issues will inherently carried over from the current range of information spaces and will likely worsen and become more complicated with the arrival of ubiquitous and seamless information space.

The demand for continual access to the information network as well as access to all the wired devices, regardless of their location, is likely to promote increase in ubiquitous network-based products and services in the IT market within the next ten years. This wave of market growth is influenced by a number of elements and factors that are themselves growing rapidly and are increasingly becoming available in the market (Lyytinen *et al.* 2004).

In terms of hardware, the series of successive waves of new IT inventions and their diffusion so far appear to follow a certain pattern known as the Kondratieff cycle, which is based on a theory that inter-relates diverse social and economic events as being integral parts of a long-term economic cycle (Shiode *et al.* 2003). Within a capitalistic society, Kondratieff proposed that economic trends tend to repeat themselves every 50-60 years (Figure 6.2.1) (Hall and Preston 1988).

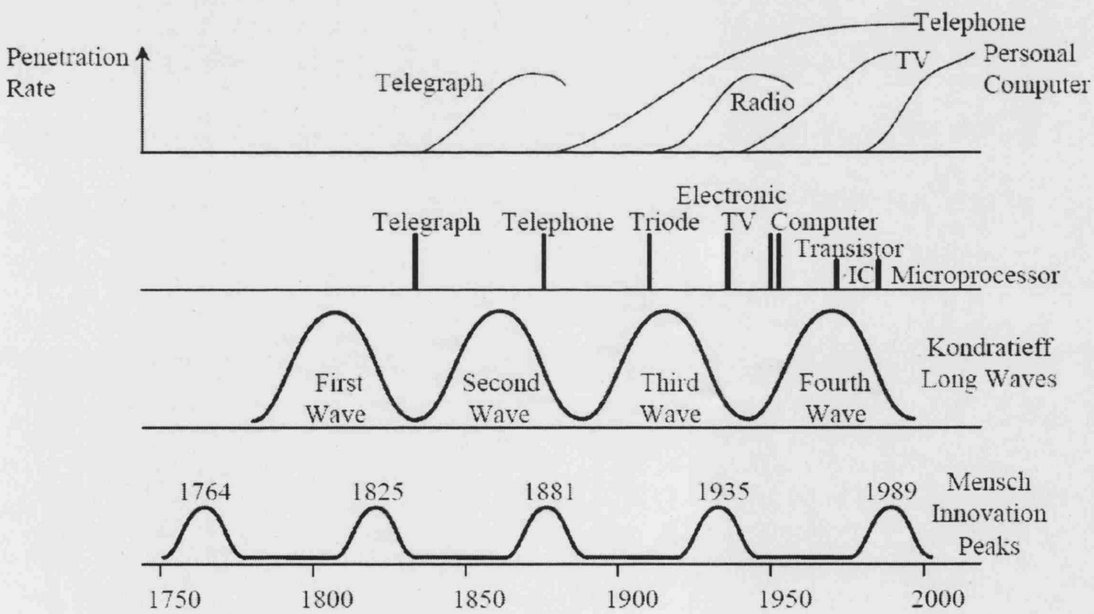


Figure 6.2.1 Schematic diagram of radical new IT innovations and the Kondratieff waves (Reproduced from Hall and Preston 1988 with permission).

This alternation of the long wave from prosperity to depression, complemented by the shorter cycles of innovation peaks, lends a dynamic trend to the economy that to a large degree becomes predictable. The cycle is strongly associated with the discovery and ingestion as well as dissemination and implementation of new technologies. Whether or not the Kondratieff wave is theoretically robust remains controversial, but there is widespread evidence, which empirically supports the idea that the economic market and innovations curve reveal common ground in their periodic behaviour.

Hall and Preston (1988) argue that the array of innovations of IT-related technologies and services observed in the 1980s can be regarded as part of the fifth wave of innovations in this particular context (Figure 6.2.1). The figure illustrates the transition of innovations and technologies where the new generation of innovations is continuously emerging under a certain frequency, occasionally replacing their predecessors. Taking this analogy further, we can argue that the ubiquitous computing-related technologies also follow the wave of innovations as a group of inventions forming the terminal period of the fifth Kondratieff wave, where these technologies will rapidly become available in the market and will promote the formation of a ubiquitous network society. This wave of innovation, in the form of the development of ubiquitous information space, will yield increased productivity and in return will promote further innovations that will form the next (sixth) wave.

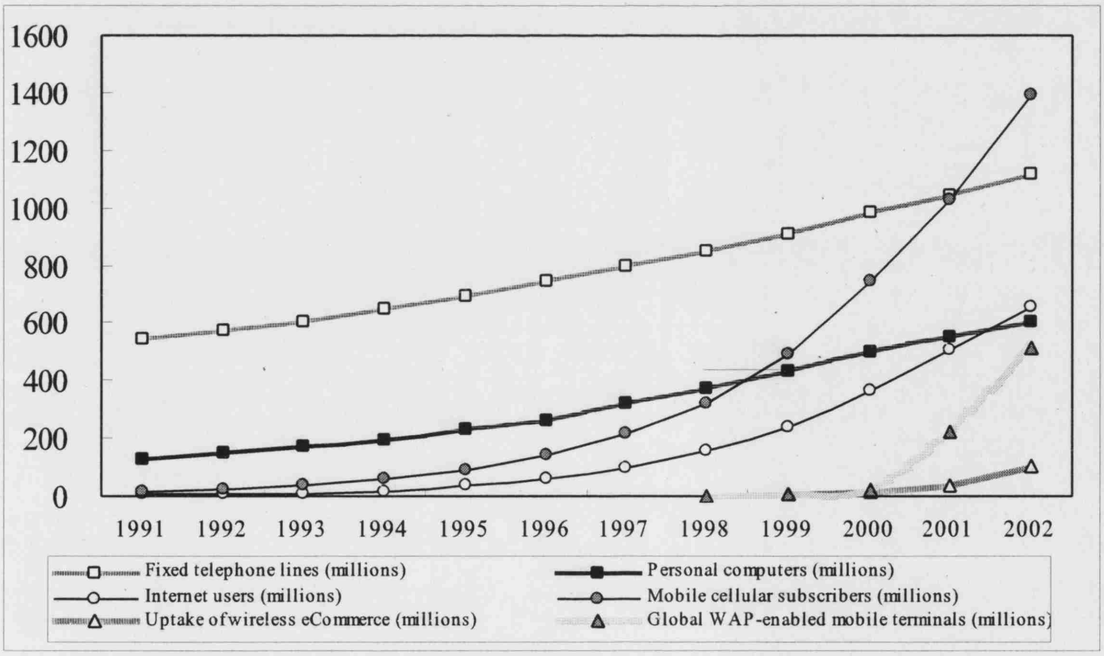


Figure 6.2.2 Growth of IT-related Services and Commodities (Shiode *et al.*, 2003)(Source: allNetDevices, ITU).

Wireless Communication Devices

One such element that will contribute towards the formation of ubiquitous network society is the development of mobile hardware including the 3rd and the 4th generations of mobile communication devices. Figures 6.2.2 and 6.2.3 respectively show the trajectory of recent increase in the various ICT-related indices, and a forecast of the penetration rate of such mobile devices in the world regions (Shiode *et al.*, 2003). The results indicate that the mobile market will come to a near-saturated state in the developed countries within the next few years, and that the rise of mobile and wireless society would be imminent whereupon the basic ground for the ubiquitous network society will be established. These mobile networks will be complemented by the increasingly available wireless computer networks provided throughout research institutes, industry, public facilities as well as individual residences. A detailed and context-based comparison of the development of mobile communications in Japan, Korea and Europe by Henten *et al.* (2004) confirm the general tendency of prevailing growth of the related communication technologies.

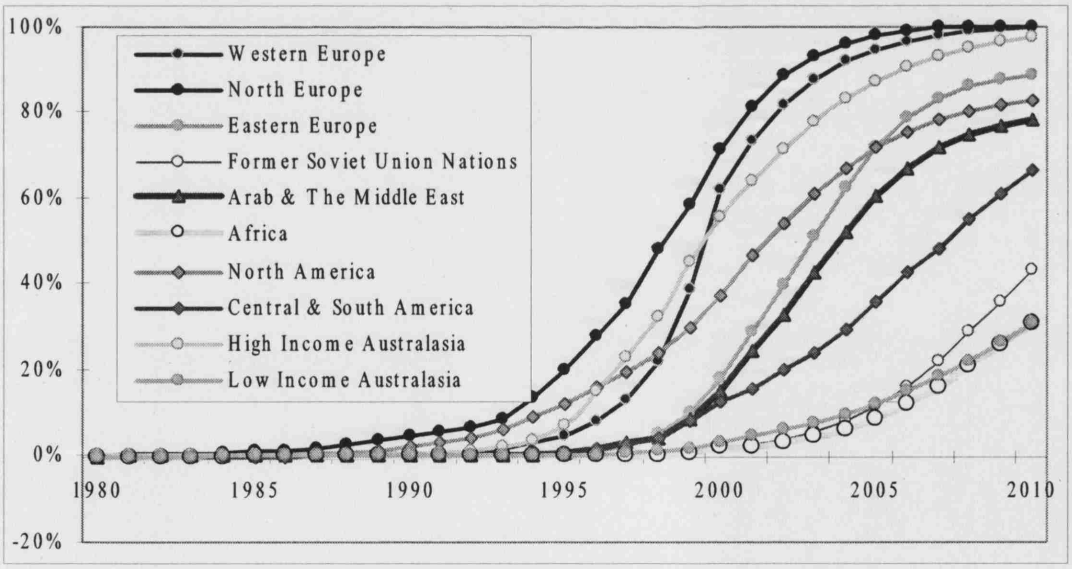


Figure 6.2.3 Prediction of the Mobile Penetration Rate within each continent over the Next Decade Using a Logistic Model (Shiode 2004).

6. CONCLUSION

Smart ID tags

Another key technology to the formation of ubiquitous network society is a small microchips, known as an IC tag, that carry basic information of the product within which it is embedded. It can be used in the place of universal product codes but is more sophisticated in that it conveys detailed information about the place of origin, date of production, conditions under which it was kept and so forth. The tags will respond to a chip reader and can be monitored full-time through the ubiquitous network. A variation of ID tags incorporates additional context-aware functions; i.e. the ability to perform certain functions according to the context or by responding to communications. For instance, an ID tag in a cloth can sense the cold climate and adjust its warmth; and a tag on a food package can send out a warning when it is due. The development of these IC tags is being closely supported by the manufacturers and industries, and they expect the tags to circulate in the market as early as from 2006.

Support from the Government and Industry

The notion of ubiquitously connected society is also rapidly prevailing among the governments and industries alike. One such example can be shown by the directions of ICT initiative taken by the Japanese government. Japan has recently readjusted its ICT initiative from their old *e*-Referendum to "*u*-Referendum," which has much stronger focus on the arrival of ubiquitous network society. Murakami (2003) and his team at Nomura Research Institute are currently revising the *e*-Japan referendum, and they are proposing *u*-Japan program, which comprises of two phases. In the first phase, *ubiquitous 1*, various information and electronic appliances, automobiles, office equipments and IC tags will become online as ubiquitous electronics, which will significantly increase the overall network accessibility and also helps the users acknowledge the state of near-continuous accessibility; and they expect to see this to take place in late 2005.

The second phase, *ubiquitous 2*, is expected to be reached after 2007, and it will build on this first step to form a reliable network that can be applied to general business use. What separates the two phases is not only the amount or the speed of the available network but several other issues that need to be resolved: these are (1) establishment of a secure environment, (2) privacy protection, (3) copyright protection and the framework for handling the digital contents, and (4) formation of a seamless online transaction system.

This movement towards ubiquitous network society is also embraced by the industry. Matsushita Co., also known as Panasonic, for instance, anticipates the arrival of such community within the next five years and identifies the market for home appliances and electric products to shift as follows:

1. Multimedia appliances (1995~2000)
2. Broadband network appliances (2000~2005)
3. Ubiquitous network appliances (2005~2010)

Other companies including IBM, Microsoft and other major computer and software vendors expect similar uptakes in ubiquitous network market, and there are several pilot studies already underway. For instance, healthcare and private nursing industry provides a network-connected electric kettle through which they monitor the health of an elderly by the pattern of its usage. Also, some grocery merchants have started to tag selected foods for tracing the date, place and their conditions, thus providing quality assurance. LBS combined with the 3rd generation mobile phones are also being increasingly used by the younger generation to search restaurants nearby and for booking a table online, or to find the location of their friends through GPS positioning. Many of these applications still appear to be developed independently and are unrelated to one another, but they are all being enabled through the use of IT network, and the users are gradually realising the convenience of using network-based products and being online.

It is expected to take several more years to integrate the various technologies and devices before a well-connected information society will be established, but the idea of being constantly connected online, and also the ability to monitor and control products online are gradually taking their shape around the notion of ubiquitous network space. In sum, the technology and hardware that support ubiquitous network society are becoming increasingly available, but we still need to consider (1) what the geography, including accessibility and opportunity provided by such seamless information space would be like; and (2) how we could incorporate such flexible utility space as part of our lives once it becomes available. It may very likely demand a new set of protocols and manners on our side to share such space with the global population.

6.2.3 Where Do We Go from Here?

This study categorised the current range of information spaces, analysed subsets of each type of space, and investigated the ways to utilise such spaces through a series of case studies. While they provide a valuable insight in understanding the current range of information spaces, the rapid growth of ICTs and information spaces is already bringing in a new breed of information space represented by the ubiquitous network space.

In terms of the geographical aspects of the newly emerging ubiquitous network spaces, we could assume that they would somewhat resemble those indicated by their predecessors in that, while online accessibility and opportunity become faster and wider, the physical end of spatial sequence bound by the physical infrastructure and geographical locations on the earth's surface will remain as the foundation of such ubiquitous network space.

When the current set of information spaces first emerged, they did not replace the conventional services that existed around the physical entities but complemented it and generated new types of demands. Similarly, the next generation of information spaces and information services may not replace the existing services, but will probably be added on top of their previous equivalents and provide different mode of services.

Therefore, in terms of the social context, we would eventually come to possess a variety of modes and spaces allotted for different activities, most of which would be essentially part of the emerging ubiquitous information space. The interface and means of communication would be different from space to space, and we may well end up with a series of personal addresses, equivalent of postal address and *e*-mail-address, assigned for each individual. Different protocols and attitude may be assumed for different means and mode of interaction. It would also involve a variety of legal issues, copyrights, privacy matters, and various other social implications.

The analysis provided in this study, if somewhat in an exploratory and fragmented manner, indicates that the current generation of information spaces are showing the same remarkable growth rate that follow the basic pattern of rank-size distribution across their whole spatial range, thus adding to its size and complexity by the day and by the minute. The case studies, on the other hand, suggest that these spaces have a profound and significant potential to serve as a new arena for social-economic and cultural-and-research activities in such way that they would enrich and enhance our ability to interact with other people across the globe as well as the spaces themselves and the elements contained therein.

The next generation of information space would almost certainly increase the complexity of our lives further more, if in return for the added convenience of seamless access to the information network and a host of new services provided by such ubiquitous network. And, judging from the growth rate of the present information space and information networks that support them, the shift to the next generation will commence before long.

The evolution of information spaces has only begun, and yet it is most likely to take us further deeply into the electronic labyrinth.

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